

NATIONAL COOPERATIVE  
HIGHWAY RESEARCH PROGRAM REPORT

**255**

# **HIGHWAY TRAFFIC DATA FOR URBANIZED AREA PROJECT PLANNING AND DESIGN**

**TRANSPORTATION RESEARCH BOARD  
NATIONAL RESEARCH COUNCIL**

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM  
REPORT

**255**

## HIGHWAY TRAFFIC DATA FOR URBANIZED AREA PROJECT PLANNING AND DESIGN

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AREAS OF INTEREST:

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FORECASTING  
(HIGHWAY TRANSPORTATION)

TRANSPORTATION RESEARCH BOARD  
NATIONAL RESEARCH COUNCIL  
WASHINGTON, D.C.

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## NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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# FOREWORD

*By Staff  
Transportation  
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Individual agencies have developed various approaches and techniques for applying system-level traffic data to specific highway design projects. For example, many state and urban area transportation agencies use traffic assignments developed in their long-range system planning activities to determine design-hour volumes at the project level. However, these techniques have not previously been documented or standardized for general use. This report provides a comprehensive compilation of the best techniques that are currently being used in urban areas to bridge the gap between system and project analyses. These techniques were identified through a survey of state and local agencies with follow-up field visits to obtain detailed information on procedural steps and typical applications. A user's manual with illustrative case studies is provided in the Appendix. This report should be of special interest to highway planners and design engineers who wish to modify their current procedures or to adopt new ones.

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Estimating traffic volumes with the accuracy needed for use in highway design has always been a complex task. Typically, the analyst uses information obtained from land-use planning, traffic forecasting (e.g., trip generation, mode split, traffic assignment), volume counts, and other data to develop design volumes. Many agencies have established various procedures for this purpose, but in most cases these procedures have not been documented for wide dissemination.

JHK & Associates collected information from numerous state and local agencies regarding currently used procedures and developed complete documentation for others to use. The procedures are grouped into ten categories—refinement of computerized traffic volume forecasts; traffic data for alternative network assumptions; traffic data for detailed networks; traffic data for different forecast years; turning movement data; design hour volume and other time-of-day data; directional distribution data; vehicle classification data; speed, delay, and queue length data; and design of highway pavements. The selected procedures were found to be applicable in many situations and to provide a basis for standardization of traffic data analysis.

These same ten categories provide the framework for the user's manual that was developed as part of this research (see Appendix). The user's manual is applicable over a wide range of analyses including systems planning, corridor or subarea studies, evaluation of alternative plans, traffic operations studies, highway design, and environmental studies. Emphasis is placed on easily applied manual techniques, but computer applications are also addressed.

To demonstrate the use of the procedures, three case studies are included—the upgrading of a limited access highway; the evaluation of an arterial improvement; and the design of a highway volume intersection. Detailed information on procedural steps is provided along with guidance regarding level of accuracy, time requirements, limitations, etc.

This report complements *NCHRP Report 187*, "Quick-Response Urban Travel Estimation Techniques and Transferable Parameters—User's Guide," which provides manual techniques for trip generation, mode split, and traffic assignment. Together, these two reports cover the full spectrum of techniques typically used in planning and design applications.

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Benevelli, Transportation Engineer; and Elizabeth D. Scullin, Senior Transportation Engineer. Morris J. Rothenberg, Senior Vice President, was the Responsible Officer.

Sincerest thanks are extended to each of the agencies and individuals who contributed time and effort in responding to interviews, completing the questionnaire, and providing documentation of available procedures.

# HIGHWAY TRAFFIC DATA FOR URBANIZED AREA PROJECT PLANNING AND DESIGN

## SUMMARY

The development of highway traffic data for highway project planning and design requires close cooperation between the users and producers of such data. Unfortunately, until the present time, there have existed no standardized procedures to enable the results of highway system-level traffic assignments, historical data, land-use information, and other factors to be translated into traffic data for highway projects.

Accordingly, this research was conducted to meet the following objectives: (1) Identify, review, and evaluate typical procedures currently being used to develop highway traffic data for project planning and design in urbanized areas; and (2) Using existing techniques to the maximum extent possible, develop a user-oriented manual containing procedures for the full range of planning and design needs, together with illustrative case studies.

A research approach was developed which would enable various procedures to be efficiently identified and evaluated. The following tasks were included:

- Task 1: Investigate Current Needs and Existing Procedures
- Task 2: Evaluate and Recommend Appropriate Procedures
- Task 3: Prepare a User's Manual with Illustrative Case Studies

A literature search was performed to identify existing documentation of available procedures. Subsequent contacts were made with more than 45 state and local governmental agencies throughout the United States. A detailed questionnaire was distributed to both the users and producers of traffic data in these agencies. Based upon the responses to the questionnaire, a number of states were chosen for follow-up personal and telephone interviews. In these interviews more in-depth information was obtained regarding promising procedures and the use of traffic data in highway project planning and design.

These findings indicate that a large percentage of highway planning and design decisions are based on the results of traffic data forecasts. At the same time, it is apparent that the quality of the input data and the analysis procedures used for these forecasts are viewed as being deficient in many respects. Some of the primary issues revealed were the following:

1. The level of detail and precision of computer traffic forecasts varies tremendously from project to project.
2. The lack of quality land-use forecasts hampers the development of high quality traffic forecasts. There are wide variations in the format and quality of data produced by agencies.
3. There is no uniformity in the types of computerized traffic assignments performed (i.e., all-or-nothing; capacity restrained; stochastic).
4. Computer assignments are often not available for all highway alternatives or for all years under study.
5. The traffic data needs for evaluation, design, and environmental analyses are often very different.
6. The responsibility for producing traffic data is often fragmented among agencies.
7. Production of adequate traffic data requires considerable effort and time as well as judgment which comes with experience.
8. A large number of explicit and implicit assumptions are made every time traffic forecasts are performed for highway project planning and design studies.

While public agencies are in partial agreement with respect to techniques for using highway traffic data, they have virtually no uniform procedures to develop those data. Thus, results of analyses in one state cannot be readily compared with results obtained from adjacent states. This problem even manifests itself among urban areas within the same state.

The need existed to identify as many of the available procedures as possible, evaluate each of the procedures, draw upon the strongest points of the evaluated procedures, and develop a set of standard procedures that could receive national distribution. In response to this need, a user's manual was prepared.

The user's manual covers 10 categories of procedures related to traffic data development, as follows:

1. Refinement of computerized traffic volume forecasts.
2. Traffic data for alternative network assumptions.
3. Traffic data for more detailed networks.
4. Traffic data for different forecast years.
5. Turning movement procedures.
6. Design hour volume and other time-of-day procedures.
7. Directional distribution procedures.
8. Vehicle classification procedures.
9. Speed, delay, and queue length procedures.
10. Traffic data for design of highway pavements.

The procedures in these categories can be used singularly or in combination, depending on the analyses to be undertaken. In most cases, manually applied procedures have been described, although computer-aided techniques are presented where appropriate.

In the area of computerized traffic forecast refinements, two procedures are recommended at the corridor or subarea level. The first is a screenline adjustment process that compares base year and future year volumes and capacities across several facilities. The second procedure uses computer-generated select link or zonal tree data to aid the analyst in defining network travel patterns.

The procedures to derive traffic data for alternative network assumptions cover four basic situations: (1) change in roadway capacity; (2) change in roadway alignment; (3) construction of parallel roadways; and (4) addition or subtraction of links. Modifications of screenline adjustments and the use of select link or zonal tree data are used to perform the analyses.

To develop data for more detailed networks, two primary approaches are subarea focusing and subarea windowing. In focusing, a more detailed network is defined within the study area, leaving the remaining network intact. In windowing, a more detailed study area network is defined within a cordon. The remaining network is then replaced by a series of external stations. Both procedures are computer-aided. They are most applicable for conducting small scale corridor or subarea studies in which detailed link and turning volumes are desired on various highways which are not shown on a systems-level network.

In order to derive traffic volumes for different forecast years, various linear and nonlinear growth curves have been developed. These growth curves are based on projected land-use growth patterns or historical trends and can be used to interpolate or extrapolate traffic volumes to alternate years. For more detailed analyses in areas where wide variations in zonal growth are expected to occur, it is recommended that select link and zonal tree data be used to determine differential growth patterns on various facilities.

There are three sets of procedures presented for deriving turning movement data--factoring procedures, iterative procedures, and "T" intersection procedures. These procedures can be applied in situations where either "directional" or "nondirectional" volume data are available.

Procedures are documented to permit design hour volumes to be determined for typical urban facilities and for facilities characterized by sharp recreational or seasonal variations. Other time-of-day procedures are useful to convert daily volume estimates to hourly data for use in design or environmental studies. In both cases, emphasis is placed on the need to adjust base year time-of-day values to reflect changing land use, geometric, or traffic conditions in the future.

The directional distribution procedures try to establish statistical relationships between directional distribution and various factors, such as time-of-day, facility type, and orientation (i.e., radial, circumferential). In lieu of these data, other procedures adjust base year directional splits using professional judgment and knowledge of future land uses (e.g., commercial, residential, industrial).

The vehicle classification procedure provides basic background relevant to the estimation of various auto-truck percentages on urban facilities. It includes a review of expected future land-use changes that would be expected to affect the distribution of vehicles on a facility.

Procedures are presented for calculating speeds, delays, and queue lengths on grade-separated facilities and on surface arterials. The analyst is able to apply different methodologies for traffic flow conditions that are under- or over-capacity. The resulting data are directly applicable to small area design analyses and to environmental analyses.

The procedures presented for highway pavement design enable traffic volume and vehicle classification data to be converted into 18-kip equivalent single-axle loadings that are directly used in the calculation of flexible and rigid pavement design needs. These procedures are applicable using vehicle classification data specific to the subject facility or average values obtained on a regional or statewide basis.

The procedures in the user's manual are applicable over a wide range of analyses. The principal types of applications include systems planning, corridor or subarea studies, evaluation of alternative plans, traffic operations studies, highway design, and environmental studies. In order to demonstrate this applicability, the procedures were applied to three case studies--the upgrading of a limited access highway; the evaluation of an arterial improvement; and the design of a high volume intersection. These case studies describe the interactions of several procedures and indicate that reasonable results can be achieved in relatively short time frames.

The study suggests future areas of research relating to traffic data development. The key areas of emphasis should be the following:

1. The effects of over-capacity highway conditions on land-use development and on the temporal and geographic distribution of traffic.
2. The development of microcomputer or hand calculator applications of several procedures.
3. The quantification of additional factors contributing to or constraining traffic growth.
4. More systematic techniques for deriving turning volumes from intersection link volumes.
5. An improved statistical base for transferring time-of-day, directional distribution, and vehicle classification data to other settings. Particular effort should be given to quantifying truck time-of-day relationships.
6. The improved specificity and standardization of traffic data for use in environmental and evaluation models.

This research project represents the first major effort to document standardized procedures for producing traffic data for use in project planning and design. Therefore, it is recommended that a training course be developed to disseminate this information to both the producers and users of highway traffic data throughout the United States.

## CHAPTER ONE

# INTRODUCTION AND RESEARCH APPROACH

## PURPOSE AND SCOPE OF PROJECT

Until the present time, there have been no nationally accepted or widely used procedures to translate the results of highway system-level traffic assignments, historical data, land-use information, and other factors into traffic data for individual highway projects. A need has been recognized not only to establish accepted procedures for translating various inputs into project traffic data, but also to specify the content, accuracy, and limitations of the data for the problem being addressed. This type of information is required to meet the diverse needs of highway designers, environmental planners, and decision-makers.

The specific objectives of this research were to: (1) identify, review, and evaluate typical procedures currently being used to develop highway traffic data for project planning and design in urbanized areas; and (2) using existing techniques to the maximum extent possible, develop a user-oriented manual containing procedures for the full range of planning and design needs together with illustrative case studies.

### Background

During the past 30 years the science of forecasting travel demand in urban areas in the United States has undergone tremendous change. Until the mid-1950's the vast majority of traffic forecasting in the United States was done by projecting traffic trend lines into the future, occasionally taking into account exogenous factors. With the advent of the high speed electronic computer and the formulation of a series of mathematical travel demand models that related travel demand to land use, urban travel demand forecasting procedures changed dramatically. Instead of only being able to forecast traffic on a facility-by-facility basis, it now became possible to forecast changes in travel demand that could be expected to occur at both the systems and corridor

level as a result of changing the transportation infrastructure. Emphasis shifted to developing long range system plans, and a great deal of credibility was placed in the computerized travel demand forecasts. Soon many transportation decisions were based on traffic projections produced "by the computer."

Research in travel demand continued to develop new mathematical models that could more accurately replicate human travel behavior. As more and more computerized travel demand forecasts were made, and as some of the transportation facilities opened for which these computerized travel demand forecasts had been made, it was soon apparent that a number of the forecasts had been far from correct. As a result, it was realized that multi-million dollar construction decisions had been based on projections that were not always reliable.

Much attention has been focussed on ways to make the mathematical models more sensitive to those variables that actually determine human travel behavior. However, in many cases the blame for errors in forecasting rests much more with the quality of the input data to the models than with the models themselves. For example, projecting future land use is a difficult and inexact science, even on a jurisdictional basis. To perform this task accurately at the level of travel analysis zones has proven to be almost impossible, yet future land use is probably the single most important input variable to the travel demand forecasting process.

Because of the amount of data that must be coded and the high cost of making travel demand forecasts, the transportation networks that have been used for travel demand projections are typically skeleton networks that simplify the actual highway system. In a computer simulation travelers are shown loading onto the network at only a limited number of entry points (zone connectors), when in reality they enter the network at many points. Traffic assignments have proven to be very sensitive to the coding of zone connectors in the network.

Because of the tremendous amount of network description data that must be developed for travel demand forecasts, general rules of thumb are often applied in order to obtain travel times and capacities for individual links. For example, both speeds and capacities are frequently defined by class of facility in the UTPS highway assignment model UROAD (115), yet both of these critical input parameters can vary widely among roadways within a particular class. Another problem which occurs because of the large data input requirements is that it becomes very easy to make subtle and largely undetectable network coding errors that affect the forecasting results.

Although problems with travel demand forecasts were recognized, the importance of the forecasts in the transportation planning and decision-making process continued to grow in the 1960's and 1970's. This was for several reasons. With the construction of urban freeways in most large metropolitan areas in the United States during the late 1950's and the 1960's, a better understanding was gained of the tremendous social, economic, and environmental impacts associated with these facilities. In recognition of the importance of these impacts, detailed socioeconomic and environmental analyses became a requirement in the evaluation of transportation alternatives. These analyses have been very dependent on a large number of detailed outputs from the travel demand forecasting process.

In addition, during the 1960's and 1970's, groups opposing highway construction projects became much better organized and required transportation planners and decision-makers to provide much more detailed justification for proposed projects. Since the primary justification for constructing most urban highway facilities has been to serve vehicular rather than person travel demand, traffic projections soon came under closer scrutiny and were often challenged by community and environmental groups.

The 1970's were a period during which highway construction costs escalated at a rapid rate, while government budgets in general and highway budgets in particular were restrained. As a result, potential highway construction projects were required to be evaluated not only on their own merits, but also in comparison with other highway alternatives. Insufficient funds were available to construct all of the facilities that were considered necessary. Expected travel demand became an important criterion in prioritizing projects.

The 1970's also witnessed a change in emphasis from the construction of new capital-intensive transportation facilities to improved management of existing facilities. In evaluating alternatives, it became necessary to analyze the expected travel demand impacts of a number of transportation system management (TSM) measures in addition to the traditional build and no-build alternatives. The standard travel demand forecasting models proved to be ineffective in estimating the impacts of many of these TSM alternatives; therefore, revised traffic forecasting procedures had to be adopted.

These changes in the transportation planning process dictated the need for improved travel demand forecasts. Subsequent research focussed on the development of better mathematical models that were sensitive to the critical variables that determined travel behavior. A second area given more attention was the quality of the land use and network description data used as input to the models. A third means to improve travel demand forecasts was to refine the assigned traffic volumes that result from the computerized travel demand process. This area, until recently, has not received a great deal of research focus, yet it is a task confronting almost all practicing travel demand forecasters. These refinements are essential if traffic forecasts are to pass reasonableness tests.

Although refinement of system-level traffic forecasts is widely practiced, until the present no standardized

procedures existed which were documented nationwide use. One of the primary purposes of the research conducted in this study was to document procedures that could be used nationwide to develop and refine highway project planning and design traffic data.

Although the research investigated the role of computerized travel demand forecasts in the development of traffic data, its focus was not on means to improve the computer forecasts themselves, but instead it focussed on the use and refinement of the data produced by computer forecasts. The user's manual produced through the research should serve to provide a means to translate the results of system-level computerized forecasts into data required for highway project planning and design studies.

## RESEARCH APPROACH

A research approach was developed that would enable various procedures used to develop highway traffic data to be efficiently identified and evaluated. The most promising procedures were later compiled into a user-oriented manual.

Three primary tasks were performed during the research, as follows:

Task 1: Investigate Current Needs and Existing Procedures. This task began with an extensive library literature search covering a wide range of related topic areas. Emphasis was placed on identifying documentation of procedures used to refine or supplement computer forecasts of travel demand, as opposed to documentation of travel demand models and their associated software packages.

Subsequent contacts were made with a number of state and local governmental agencies throughout the United States. A detailed questionnaire (Chapter Two) was distributed to both the users and producers of traffic data in these agencies. On the basis of the responses to the questionnaire, a number of states were chosen for follow-up personal and telephone interviews. In these interviews more in-depth information was obtained regarding promising procedures and the use of traffic data in highway project planning and design.

Task 2: Evaluate and Recommend Appropriate Procedures. The approach used in this task was to evaluate a large number of promising procedures for potential inclusion in the user's manual to be developed in Task 3. To accomplish this effort, series of evaluation criteria were established to serve as a basis for comparison. The available procedures within various categories were compared whenever possible using these criteria. The categories and criteria used in the study are documented in Chapter Two.

Using the findings obtained from the evaluation and knowledge of the current state of the art obtained from Task 1, a set of procedures was recommended for use by practitioners. These procedures were tested using data from actual traffic forecasting studies wherever possible. These results and subsequent modifications to the procedures became the basis for developing a user's manual.

Task 3: Prepare a User's Manual with Illustrative Case Studies. A primary thrust of the research effort was to develop a user-oriented manual of field-tested procedures. The recommended procedures from Task 2 were packaged along with three illustrative case studies as the basis for the manual (see Appendix to this report).

As a final step, the findings obtained from the development of the procedures and case studies were used to identify future research needs in this area. These needs are documented in Chapter Four of this report.

## ORGANIZATION AND USE OF THE RESEARCH REPORT

This research report is structured to provide pertinent information to transportation managers and to traffic planners and designers regarding the findings of NCHRP

Research Project 8-26 which resulted in the documentation of a number of procedures for the development of highway traffic data for project planning and design in urban areas.

Chapters One through Four of the research report document the project findings, applications, and conclusions, which will be of primary benefit to administrators and project managers. This information will also provide traffic planners and designers with background relating to the technical procedures presented in the accompanying user's manual.

Exhibit 1 in Chapter Two provides a copy of the questionnaire sent to highway agencies around the country together with summary data of the responses to a number

of the questions. The user's manual provided in the Appendix, represents a state-of-the-art presentation of procedures that can be used to refine, detail, and utilize traffic volume data obtained from computerized traffic forecasts. This user's manual is primarily for use by traffic analysts who must provide suitable traffic data to highway planners, designers, and environmental planners.

The user's manual provides an overview of the various uses of traffic data, followed by detailed descriptions of analysis procedures covering 10 related categories. Three case studies are included to illustrate the application of these procedures to typical highway planning and design situations. The manual is self-contained and requires no reference to other parts of this research report.

## CHAPTER 2

# FINDINGS

## TRAFFIC REFINEMENT ISSUES

In order to obtain in-depth information about the development and use of traffic data for highway project planning and design, a three-stage analysis process was used:

1. A literature search was conducted.
2. A questionnaire covering various issues was sent to a number of agencies.
3. Personal interviews were conducted with selected users and producers of traffic data.

The literature search concentrated on identifying existing documentation of procedures available from research findings and agency reports. Much of the pertinent and usable information related to deriving time-of-day, directional distribution, or design hour volumes from average daily traffic (ADT) volumes or from traffic counts taken during specific periods of time at certain times of the year.

Two documents reviewed were user manuals on traffic refinement procedures for computer model output of travel demand. One article focused on generating turning movements from computer model output, while several documents pertained to specific uses of traffic data, such as for highway design or environmental (i.e., air, noise, energy) studies.

Many of the documents received from agencies were reports on studies that they had performed. Generally, the methodologies used in the studies were not discussed in enough detail to be useful as procedure documentation; however, the information was used to develop follow-up questions for the personal interviews.

In the second stage, a questionnaire was developed which was designed to cover various issues relating to traffic data development and use for highway project planning and design. A copy of the questionnaire is included in Exhibit 1.

Questions relating to departmental organization were asked to determine the relationships between traffic data providers and users and to obtain the names of persons to contact for additional information. Several questions related to the type and availability of traffic count data that are required for certain analysis procedures. A number of questions related to the type and use of

system-level computerized travel demand forecasts, because these forecasts serve as the base for the development of most project-level traffic data. Next, respondents were asked to describe the procedures they used for refining computerized system-level travel demand forecasts for use at the project level. Information regarding traffic data used for evaluation of alternatives, environmental analyses, and highway design was also solicited. Finally, questions were asked about procedures for forecasting time-of-day characteristics of traffic, vehicle classification data, and speed, delay, and queue length data.

The questionnaire was sent to 45 governmental agencies responsible for developing project-level traffic data. Questionnaires were received from agencies in 38 of the 45 agencies contacted. Summary of questionnaire results from 38 agencies are displayed on the questionnaire. The number of respondents is shown in parentheses for each response. The total number of respondents answering any one question may vary. Some agencies answered more than one response to some questions and did not answer others.

Upon receipt of the completed questionnaires, personal interviews were conducted with developers and users of traffic data at both the state and local level in a total of 10 states. In developing a list of agencies to visit, two primary selection criteria were applied: (1) geographic distribution, and (2) availability of promising procedures. During these interviews in-depth questions were asked relating to the responses provided in the questionnaire, particularly regarding promising procedures and problems encountered in the use of traffic data. In addition, a number of follow-up telephone conversations were conducted with questionnaire respondents who were not able to be personally interviewed.

The following sections describe the major findings from the questionnaire responses and the personal interviews, segmented into various categories. In many cases, the personal interviews provided insight into specific techniques that had been summarized in the questionnaire responses. These findings have not been subjected to statistical analysis and are applicable only to the responding agencies. Therefore, the findings should only be used for informative purposes.

Exhibit 1 Questionnaire for NCHRP Project 8-26:  
Development of highway data for project planning and design in urbanized areas.

DATA ABOUT PERSON BEING INTERVIEWED:

Name:

Title:

Address:

Telephone Number:

Brief description of interviewee's traffic forecasting responsibilities:

DEPARTMENTAL ORGANIZATION

1. Could we obtain an organizational chart which shows how the sections responsible for the collection, analysis, and forecasting of traffic data fit into the departmental structure?

2. Please identify the section within the department which is responsible for each of the following:

(a) Traffic counting

Name of section:

Name of responsible person:

Telephone number:

(b) Analysis of traffic count data

Name of section:

Name of responsible person:

Telephone number:

(c) Systems planning

Name of section:

Name of responsible person:

Telephone number:

(d) Traffic forecasting for systems planning

Name of section:

Name of responsible person:

Telephone number:

(e) Highway project planning and evaluation

Name of section:

Name of responsible person:

Telephone number:

(f) Traffic forecasting and traffic data analysis for project planning and evaluation

Name of section:

Name of responsible person:

Telephone number:

(g) Environmental analyses for project planning

Name of section:

Name of responsible person:

Telephone number:

(h) Preparation of traffic data for environmental analyses

Name of section:

Name of responsible person:

Telephone number:

(i) Highway design

Name of section:

Name of responsible person:

Telephone number:

## Exhibit I Continued

- (j) Traffic forecasting for highway design  
 Name of section:  
 Name of responsible person:  
 Telephone number:
- (k) Traffic operations analysis for highway design  
 Name of section:  
 Name of responsible person:  
 Telephone number:

3. In addition to the groups identified above, which other sections within the department use traffic data?

Typical Responses:

- |                       |                          |
|-----------------------|--------------------------|
| . Financial analysis  | . Maintenance            |
| . District engineers  | . Right-of-Way           |
| . Safety              | . Research               |
| . Structures (bridge) | . Materials (Geotechnic) |
| . Developers          | . Citizen Groups         |

4. For those sections which are responsible for forecasting and analyzing traffic data for highway project planning and design, could we obtain a job description for section staff members, including educational requirements?

Several responded.

5. What is the role of MPO's in providing traffic data for use in highway project planning and design studies?

- |                                      |      |
|--------------------------------------|------|
| . Land use/socioeconomic projections | (13) |
| . Traffic forecasts                  | ( 6) |
| . Perform traffic counts             | ( 6) |
| . Policy guidance                    | ( 2) |
| . No role                            | (14) |
| . Other                              | ( 3) |

#### EXISTING TRAFFIC DATA

1. Which of the following traffic counts are made as part of highway project planning and design studies?

- (a) Road tube counts Yes (38) No (0)  
 How long are counts made at each location?  
 24hr (15); 48hr (14); 3 to 7 days (4); 2 weeks (2)  
 What time increment is reported?  
 15 min (4) 30 min (1) 1 hr (32) 24 hr (11) Other (1)

What type of correction factors are applied to the count data?

- |                 |                |            |
|-----------------|----------------|------------|
| . Axles (15)    | . Daily (11)   | . ADT (2)  |
| . Seasonal (22) | variation      | . None (3) |
| variation       | . Monthly (15) |            |
|                 | variation      |            |

- (b) Turning movement counts Yes (37) No (1)  
 How long are counts made at each location?  
 4-6hr (8); 8-12hr (17); 14-16hr (7); 24hr (2)  
 What time increment is reported?  
 15 min (20) 30 min (3) 1 hr (13)

What type of correction and expansion factors are applied to the count data?

- |              |                 |             |
|--------------|-----------------|-------------|
| . ADT (20)   | . Seasonal (12) | . Other (5) |
| . Daily ( 4) | . Diurnal ( 2)  | . None (7)  |

## Exhibit I Continued

- (c) Vehicle classification counts Yes (37); No (1)  
How long are counts made at each location?

3-4hr (3); 6-12hr (19); 14-24hr (13)

What time increment is reported?

15 min. (2); 60 min. (33)

2. Are any other traffic count data normally requested as part of a highway project planning or design study?

- . Pedestrian (4)
- . Directional split (5)
- . Design hour volume (7)
- . High occupancy vehicles (2)
- . Other (2)

## TRAFFIC FORECASTING

1. Is a statewide travel demand forecast performed by your department? If so, is it computerized and for what years is traffic forecast?

Yes (13); No (23)

If yes, computerized? Yes (8); No (4)

If yes, time increments used? 5 yr (2); 10 yr (1); 20 yr (5); over 20 yr (2)

2. What urban areas within your state have ongoing computerized travel demand forecasting processes? Are highway project planning and design traffic data based upon these computerized forecasts?

Virtually all urban areas reported have computerized processes. Highway plans based on forecasts? Yes (26); No (2)

3. What type of regular traffic counting program does the department have?

- . Periodic counts
- . Permanent count stations (24) .. 1 yr (6)
- . Seasonal stations (5) .. 2 yr (4)
- . Cordon counts (3) .. 4 yr (2)
- .. Over 4 yr (1)

4. Are annual reports summarizing basic traffic data issued? Could we obtain copies of any which are used to develop correction factors or growth factors which are used in traffic forecasting?

Frequency of issue: 1 yr (24)  
2 yr (3)  
Over 2 yr (1)  
Annual map only (1)

5. Do you have standard request forms for traffic counts? Yes (11); No (24)  
If so, could we obtain a copy of each? If not, how are traffic counts requested?

- . Several obtained
- . Other requests via . memo (19)
- . phone (8)

6. What is the average turnaround time from date of request to actual receipt of traffic count data?

- . Less than 2 wk (13)
- . 2-4 wk (17)
- . Over 1 month (4)

7. Could you provide us with copies of traffic count data collection and data summary forms?

Several provided.

## Exhibit I Continued

3. Who has responsibility for producing the computerized travel demand forecasts in each urban area?

. State DOT (34)  
 . MPO (15)  
 . Local Agencies (4)  
 . Consultants (1)

4. Are separate computerized forecasts typically made for each alternative being studied in a project planning study? What years are forecasts normally made for?

. Base year (14) . 15 yr (3)  
 . Construction year (5) . 20+ yr (33)  
 . 5 yr (4)  
 . 10 yr (9)

5. Are standardized FHWA or UMTA procedures used in performing the travel demand forecasts? Is so, are they flowcharted? Is the process documented? Could we obtain copies of documentation, including flow charts, if available?

. FHWA only (6)  
 . UTPS only (5)  
 . Both FHWA and UTPS (22)  
 . Other (3)

Very few are flow charted.

6. When were the models last calibrated? Has any work been done to validate or update the models since that time?

Last calibrated		Validated since then
. Before 1970 (5)	. 1977-1979 (10)	. Yes (18)
. 1970-1972 (4)	. 1980 or later (4)	. No (13)
. 1973-1976 (12)		

7. Do you perform base (present) year validation runs as part of the computerized travel demand process for highway project planning or design studies?

. Yes (20)  
 . No (14)

8. Do you use a more detailed zone system and code a more detailed highway network within the corridor being studied?

. Yes (13)  
 . No (21)

9. Who provides the land use (socio-economic) data that is used in the forecasting process? What land use (socio-economic) variables are used? For what years are these forecasts available?

Providers:	Number of data variables used:	Years available:
. MPO (15)	. less than 5 (15)	. 2000 (17)
. Local Agencies (6)	. 6-10 (9)	. 2005 (3)
. State DOT (4)	. over 10 (1)	

10. What type of modal choice process is used in the travel demand forecasts?

Computer models used?	Various manual and computer models used.
. Yes (17)	
. No (6)	

11. Is your computer assignment process all-or-nothing, capacity-restrained, or stochastic? Which model do you use for computerized forecasts? Do you code global speed/capacity tables or separate speeds and capacities for each link in the network?

Type of Assignment:	Coding used for speeds and capacities:
. All-or-nothing (16)	. Global values (5)
. Capacity restrained (14)	. Link specific values (17)
. Stochastic (3)	

## Exhibit I Continued

12. Are your assignments ADT, peak period, or peak hour? If they are peak period or peak hour, what factors do you apply to 24 hour trip tables to obtain peak period or peak hour trip tables for assignment?

ADT (31)  
 Peak Period ( 3) - Home interview survey results, diurnal  
 Peak Hour ( 0) count data.  
 AWDT ( 2)

13. Do your assignments produce turning movements at major intersections?

. Yes (30)  
 . No ( 6)

14. Do you plot computerized assignments manually or use computer plots of traffic assignments?

. Manually (14)  
 . Computer (16)  
 . Both ( 6)

15. In areas where computerized traffic assignments are not available, how do you perform traffic forecasts? Is this process documented? Is so could we receive a copy of the documentation?

. Historical trends (29)  
 . Regression equations ( 2)

Processes were rarely documented.

16. Has your department analyzed high occupancy vehicle priority treatment alternatives? If so, what travel demand forecasting procedures were used? Could we receive documentation of these procedures?

. Yes (17)  
 . No (17)

Procedures:

. Manual pivot point (1)  
 . NCHRP 187 Quick Response (1)  
 . Manual diversion curves (1)  
 . FREQ models (2)  
 . Other (5)

Documentation provided for most procedures.

TRAFFIC REFINEMENT PROCEDURES

1. Has your agency adopted standardized procedures for refining computerized system level travel demand forecasts for use at the project level? Is so, are these procedures documented? Can JHK receive a copy of the documentation? If standardized procedures have not been adopted for refining system level forecasts, describe how refinements are normally made?

. Yes (13)  
 . No (13)

Received documentation for available procedures.

2. For any refinement procedures used by your agency in developing project level traffic forecasts, please provide the following information: Typical responses follow:

(a) Give a basic description of methodology.  
 . Use historical trends ( 9)  
 . Check land use ( 3)  
 . Professional judgment (10)

## Exhibit I Continued

- (b) What are the required data inputs?
    - . Historical traffic counts (10)
    - . Turning movements (3)
    - . Land use (base and future "years") (8)
    - . Traffic assignments (4)
  - (c) What are the manpower, training, and cost requirements?
    - . Time consuming (11)
    - . Other variable answers.
  - (d) What level of accuracy is required of the computer forecasts?
    - + 10% (5)
    - + 5% (1)
    - + 15% (1)
    - + 20% (1)
  - (e) Are there built-in biases in the procedure?
    - . Requires knowledge of study area (11)
    - . Doesn't account for induced land use changes (11)
    - . Uses straight line extrapolation (1)
    - . All local roads must be manually assigned (1)
    - . Based on unreasonable land use forecasts (1)
  - (f) Are reasonableness checks used to check outputs of the procedure?
    - . Yes (16)
  - (g) In what types of applications has the procedure been used?
    - . System planning (6)
    - . Corridor studies (2)
    - . Highway design (8)
    - . Evaluation of alternatives (1)
  - (h) Have there been problems in applying the procedure?
    - . Computer turnaround time (1)
    - . Unavailability of data (1)
    - . Inconsistencies (1)
    - . Unreasonable growth rate (1)
    - . Difficult to comprehend future conditions (1)
  - (i) What suggested improvements to the procedure do you have?
    - . More current traffic counts (1)
    - . More current land use data and forecasts (1)
    - . More detailed networks and zones (1)
    - . Bring policy forecasts to reality (2)
3. How do you adjust system level forecast data in cases in which the forecast year for the highway project is different than the forecast year for the computerized systems level forecast?
- . Extrapolate or Interpolate (11)
  - . Use historical growth rates (14)
  - . Factor trip table (2)
4. Do you have procedures for deriving turning movement data from link volume data? If so, are they documented, and could JHK receive a copy of the documentation? If documentation is not available, please describe the procedure.
- . Yes (1) - Documentation sent
  - . No (4)
- Most agencies use professional judgment.

## Exhibit I Continued

5. Do you have procedures for developing traffic volume data for a more detailed network than that in the systems forecast? If so, are they documented, and could JHK receive a copy of the documentation? If documentation is not available, please describe the procedure.

- . Windowing technique (3)
- . NCHRP Report 187 Quick Response (2)
- . Professional judgment (3)

6. How do you derive traffic volume data for alternative network assumptions for which separate travel demand forecasts have not been prepared? If such procedures are documented, could JHK receive a copy of the documentation?

- . Select link analysis (3)
- . Professional judgment (11)

## TRAFFIC DATA FOR EVALUATION OF ALTERNATIVES

1. What traffic data are usually produced for the evaluation of highway project alternatives?

- |                            |     |                      |     |
|----------------------------|-----|----------------------|-----|
| . ADT                      | (8) | . Speeds             | (1) |
| . Diurnal percentage       | (5) | . V/C ratios         | (1) |
| . Directional distribution | (2) | . Turning movements  | (2) |
| . Truck percentage         | (4) | . 18-kip equivalents | (1) |
| . VMT                      | (3) |                      |     |
| . VHT                      | (2) |                      |     |

2. Is a standardized format used for presenting traffic evaluation data? If so could we receive a copy of the specifications for presenting the data or a copy of a sample report which shows how traffic evaluation data are presented?

- . Yes (8)
- . No (23)

Some documentation received.

## TRAFFIC DATA FOR ENVIRONMENTAL ANALYSES

1. What traffic data are normally produced for input to environmental analyses?

- |                          |     |                            |     |
|--------------------------|-----|----------------------------|-----|
| . ADT                    | (6) | . VMT                      | (3) |
| . Speed                  | (1) | . Diurnal percentages      | (1) |
| . Vehicle classification | (7) | . Directional distribution | (1) |
| . Design hour volume     | (4) |                            |     |

2. If the data which are input to environmental analyses are prepared in a standard format, would you provide us with a copy of the forms which are used for preparing the data?

- . Yes (9)
- . No (18)

Some forms provided for specific models.

3. What environmental models which your agency uses require traffic data, and what traffic data are required as input to each model?

- |                                |      |                  |     |
|--------------------------------|------|------------------|-----|
| Air Quality:                   |      | Noise:           |     |
| . MOBILE 1                     | (15) | . FHWA procedure | (3) |
| . CALINE                       | (14) | . STAMINA 1.0    | (8) |
| . APRAC                        | (2)  | . SNAP           | (6) |
| . HWAY 2                       | (1)  | . HUSH           | (1) |
| . Kansas Air Pollution Package | (2)  | Energy:          |     |
| . Other                        | (2)  | . NCHRP 20-7     | (1) |
|                                |      | . ENERGY         | (4) |

## Exhibit 1 Continued

## TRAFFIC DATA FOR HIGHWAY DESIGN

1. What traffic data are normally produced for input to highway design studies? How are these data used in highway design?

. ADT	(34)	. Turning movements	(13)
. Diurnal percentages	(30)	. Geometrics	( 2)
. Directional distribution	(11)	. Speed	( 2)
. Truck percentages	(27)	. Accidents	( 1)

2. Are standardized formats used for highway design traffic data? Is so, would you provide us with a copy of the format for presenting these data?

. Yes (13);  
 . No (21)

Several forms provided.

3. What capacity analysis procedures is your agency presently using, both on arterial streets and freeways?

. 1965 Highway Capacity Manual	(22)
. TRB Circular 212	(10)
. Leisch Charts	( 2)
. Critical Lane Volumes	( 5)
. AASHTO	( 3)
. NCHRP 187 - Quick Response	( 1)
. V/C ratios	( 2)

## SPECIFIC PROCEDURES FOR PRODUCING TRAFFIC DATA

1. Do you have procedures for forecasting changes in the percentage of traffic which travels during the AM and PM peak hours, changes in directional distribution by time of day, and changes in diurnal curve characteristics? If these procedures are documented, would you send JHK a copy of the documentation? If not, please describe the procedures.

. Yes (11) - Historical count trends (8); land use changes (2)  
 . No (21)

2. How do you forecast changes in vehicle mix? If you have documented these procedures would you send the documentation to JHK?

. Historical classification count trends (12)  
 . No procedure used (12)

3. How do you forecast operating speed data? Do you have special procedures for calculating average operating speeds in the vicinity of intersections or bottlenecks where traffic is stopped at certain times? If your procedures are documented would you send the documentation to JHK?

. V/C ratio and speed relationships	(7)	. Engineering judgment	(4)
. Speed and delay studies	(5)	. No procedure used	(5)
. 1965 Highway Capacity Manual Curves	(3)		

4. Are you required to perform queuing analysis for intersections or at bottlenecks? Is so, what procedures do you use? Do you use special procedures for calculating queues where demand exceeds capacities? Would you provide JHK with a documentation of your queuing analysis procedures?

. No (18)  
 . Yes (10) - Poisson distributions (3); Alternate arrival method (1); engineering handbook (1); 1965 Highway Capacity Manual (3); AASHTO (2)

No special procedures cited for over-capacity conditions.

## Role of the Metropolitan Planning Organization in Producing Traffic Data

Metropolitan Planning Organizations (MPO's) play a variety of roles in providing traffic data for use in highway project planning and design studies. In 14 states, the MPO plays no role in providing traffic or socioeconomic data for use in the traffic forecasting process. Few MPO's perform the traffic forecasts or provide traffic count data; approximately half of the MPO's mainly provide land-use/socioeconomic data and policy guidance. In the vast majority of states the state DOT is the agency primarily responsible for developing facility level traffic data for major highway improvements in urban areas, while the MPO's role is to provide selected input data and policy guidance.

## Traffic Data Collection

All agencies conduct some type of regular counting program. Two-thirds of the agencies have permanent counting stations; one-third count major state highways at least once every 2 years, and less than 10 percent report seasonal counts. A majority of states publish an annual report of traffic volumes, although some now only publish an annual traffic flow map. The permanent count stations are important because they provide good historical trend data, diurnal curve information, and indications of seasonal, monthly, and daily traffic variations.

All of the responding agencies take road tube counts, usually for periods of 24 or 48 hours at each location. Most agencies report the counts in 60 minute intervals. Two-thirds of the responding agencies apply seasonal correction factors, one-third apply axle and daily variation factors, and three states do not adjust their counts. It would appear that in a number of cases additional refinements to road tube count data are called for if these data are to be useful in the development of project level traffic forecast data.

All agencies, but one, take turning movement counts. Most counts are for 8 to 12 hours, with the remainder evenly split for shorter and longer durations. Two-thirds of the agencies report in 15-minute time increments and the remainder report in 60-minute increments. The majority of the agencies use an expansion factor to a 24-hour count, and several apply a seasonal factor. In those states where only 60-minute time intervals are reported, peak hour turning movement volumes may be underreported if the peak hour does not correspond to the reporting period. In most states, however, data are collected during peak hours; therefore, a key data input to the development of future year turning movement data is almost universally available.

All agencies, but one, have vehicle classification counts available. Most counts range from 6 to 12 hours with one-third ranging from 14 to 24 hours. Almost all of the states report these counts in 60-minute increments, which are then factored up to 24-hour values based on road tube counts. Because truck percentages are quite different during the hours that are not normally counted, truck ADTs are often misreported. In several states this has resulted in inadequate pavement thickness design.

Two-thirds of the respondents do not use a standard request form for traffic counts, relying on a memo letter or a phone call for traffic count requests. The average turnaround time for traffic count data is 2 to 8 weeks, depending on the type of data requested and the staff work load at the time of the request. The length of time required to obtain traffic count data must be incorporated into the development of schedules for producing highway traffic data, particularly in those states where slow turnaround times are common.

## Traffic Forecasting

Statewide traffic forecasting is performed in a minority of the states surveyed with two-thirds of the statewide forecasts computerized. All but two of the agencies responded that the urban areas within their state have ongoing computerized travel demand forecasting processes, and that highway project planning and design traffic data are based on these forecasts. The state DOT's are mainly responsible for producing the computerized forecasts within the urban areas, while the MPO is in charge of the forecasts in a number of the larger urban areas. A few agencies employ consultants to perform their traffic forecasts.

Most of the responding agencies run separate computerized traffic forecasts for each highway alternative being evaluated in a project planning study. All but four of these agencies use standardized FHWA (104, 111) or UMTA (115) models for developing travel demand forecasts, many using a combination of the two modeling chains. Typically there is an FHWA modeling base combined with a few UTPS programs. A few agencies have developed supplemental programs to work with the FHWA/UTPS packages.

Three-quarters of the traffic forecasting models have been calibrated since 1973, with half of these calibrated since 1977. Ten percent have not been calibrated since they were developed in the late 1960's. Several states mentioned they were waiting for the 1980 census population and land-use data to recalibrate their models. Approximately 60 percent of the models have been validated since they were calibrated, and the same number of agencies perform base year validations as part of their computerized travel demand forecasts.

In the majority of the states, the MPO's and local governments provide the land-use/socioeconomic data for input to the forecasting process. Approximately two-thirds of the states use five or fewer variables in the model, and most states have available land-use forecasts for every 10 years up to the year 2000. A few states are currently developing forecasts for the year 2005, but generally system-level traffic forecasts are not available for the years for which facilities are presently being designed (i.e., construction year plus 20 years).

The agencies are equally split on using all-or-nothing or capacity restraint assignment processes. Only three agencies responded that they use a stochastic assignment process. Several agencies indicated they had capacity restraint capability but did not always exercise it either because of the costs involved or because they would rather manually restrain the roadways. Most of the agencies code specific speed and capacities for each link in the network. However, these speeds/capacities may be based on facility type and the number of lanes instead of on actual conditions.

The majority of the states produce 24-hour traffic assignments in those urban areas where computerized forecasts are performed. A constant peak hour factor of 8 to 10 percent is used, depending on the type of facility, historical count trends, and knowledge of future land use. Most of the agencies have the FHWA PLANPAC (104, 111) capability of producing turning movements but they do not exercise it on all runs. The agencies are split equally on manual versus computer plots, and several agencies use both, depending on the extensiveness of the project.

## Traffic Refinement Procedures

Few of the agencies reported that they had standardized procedures to refine computerized system-

level traffic forecasts for use at the project level. Almost all of the documented refinement procedures involved some type of comparison between base year simulated and actual traffic volumes. If such refinement procedures are to be used in agencies which do not presently use them, base year validation runs would have to be made in the states that do not presently do so. Undocumented procedures obtained with the responses typically combine an extensive amount of engineering judgment with local knowledge of historical traffic volume and land-use changes. Few agencies have specified a level of accuracy required of the computer forecasts in matching base year traffic volumes on the facilities being studied.

Several problems associated with the refinement procedures presently in use were cited. By factoring forecast volumes up or down by as much as base year simulated volumes are over or under base year traffic count data, the refined future year traffic volumes tend to be biased toward existing land-use patterns. Therefore, changes in traffic volume due to large new developments may be inadvertently lowered or raised more than is appropriate. In addition, almost all the documented refinement procedures are time consuming and require that considerable professional judgment be applied. Additional expense is often involved in obtaining base year traffic count data throughout the entire study area affected by a proposed roadway improvement.

The majority of agencies use growth factors derived from historical trends or from interpolation/extrapolation curves to adjust system-level traffic forecasts in cases where the forecast year for the highway project is different from the forecast year for the computer forecast. The exact year in which planned land-use developments will occur is often not taken into account.

Most agencies have turning movement capability within their computerized traffic assignment processes. However, several agencies responded that the turning movement data from the computerized process are not usable without substantial refinement. Of those states that do not forecast turning movement data with the computer, engineering judgment based on historical counts is the most common methodology employed.

Most states do not have procedures for developing traffic volume data for a more detailed network than that used in a system-level traffic forecast. Several states indicated that their highway networks were already detailed enough, thus obviating this need. Other states use various manual assignment procedures, windowing techniques, and/or engineering judgment.

Approximately one-half of the respondents indicated that separate travel demand forecasts are made for all alternative network assumptions. The remainder use engineering judgment or supplemental computer data to redistribute trips.

In areas where computer traffic assignments are not available, the use of historical traffic trends to forecast traffic is widespread. In these cases, at least cursory consideration is given to planned land-use changes in the study area surrounding a proposed highway improvement.

#### Traffic Data for the Evaluation of Alternatives

Very few of the respondents reported that they have a list of standardized traffic data that are produced for use in the evaluation of alternatives. Data requirements vary from project to project depending on the critical issues associated with each project. Most agencies do perform some type of benefit-cost analysis during project planning studies. In addition, traffic data are normally included in some type of evaluation report or matrix used by decision-makers to choose among alternatives.

#### Traffic Data for Environmental Analyses

Traffic data are required for three major categories of environmental analysis: air quality, noise, and energy consumption. These types of analyses are performed in almost all states as part of the environmental impact statement process, although simplified procedures are usually used where impacts are not expected to be significant.

Most agencies responded that they used some version of the air quality computer models MOBILE (33), CALINE (12, 100), and HIWAY (78) for emissions and dispersion analyses. These models require hourly traffic data stratified by vehicle class and by operating speed categories. Although intersection-level air quality analyses are not performed in most states, these analyses have recently been performed with a greater degree of regularity.

Virtually all agencies that perform energy analyses base these analyses on procedures developed by the California Department of Transportation and contained in the U.S. Department of Transportation Manual Energy Requirements for Transportation Systems (102). These procedures require average daily traffic data throughout the design life of the facility. These data must be stratified by vehicle class, congestion level, and operating speed.

The most commonly used noise models are those based on the FHWA Highway Traffic Noise Prediction Method (10, 105, 110) and its computerized versions SNAP (2, 14) or STAMINA (83). These models require as input data level-of-service "C" auto volumes, operating speeds, and design hour truck volumes.

#### Traffic Data for Highway Design

The major uses of traffic data in highway design are for capacity analyses and pavement design. Two-thirds of the agencies report that they exclusively use the 1965 Highway Capacity Manual (38) for capacity calculations on arterial streets and freeways. One-third are using the interim capacity materials in TRB Circular 212 (45), and scattered agencies are using the Leisch tables (35), other critical movement analyses, and/or AASHTO (6) procedures.

Most agencies report that they use procedures outlined in AASHTO's Interim Guide for Design of Flexible Pavement Structures (5) for pavement design. These procedures require that annual vehicle classification data be converted into equivalent 18,000-pound single-axle loads (18-kip equivalents) for all years during the design life of the pavement structure.

#### Other Data Requirements

Almost all agencies report that system-level traffic forecasts are performed using 24-hour data. Design-hour or peak-hour volumes are then derived by multiplying daily volumes by a peak-hour percentage. In almost all states the peak-hour percentage used is either a standard percentage determined by roadway type or a percentage derived from historical traffic count data on the facility being studied. In the few cases where peak-hour percentages are changed from base year conditions, these changes are based primarily on professional judgment or diurnal data from other facilities with traffic characteristics similar to those forecasted for the facility under study.

Most agencies report that base year directional distribution and vehicle classification percentages are assumed to hold for future years. For new facilities

percentages are typically derived from similar facilities elsewhere in the same urban area. In some cases these percentages are modified using professional judgment to account for new land use developments that are forecasted to occur in the area of the facility being studied.

Most of the responding agencies use volume-to-capacity (V/C) ratios, or speed and delay studies to forecast highway speed data. Some agencies assume no difference between base year and future year speeds. No responding agency had special procedures for calculating speeds in the vicinity of intersections or bottlenecks where traffic is stopped at certain times. Similarly, few of the responding agencies are required to perform queuing analyses for intersections or bottlenecks, or to use special procedures for calculating queues where demand exceeds capacity. The agencies that perform these analyses use either the 1965 Highway Capacity Manual (38), Poisson distributions, or a measurement of delay procedure.

### PROCEDURES TO PRODUCE TRAFFIC DATA

On the basis of the procedures identified during the literature search, interview processes, and subsequent development and refinement of additional methods, a set of procedures has been prepared that can be used to develop traffic data for highway project planning and design. These procedures, presented in detail in the Appendix (User's Manual), represent a combination of existing techniques and new or modified procedures.

A total of 10 categories of procedures were identified for consideration. These categories are given in Table 1. The categories include procedures to refine and detail

system-level link-volume forecasts (categories 1 through 4) and procedures to derive specific traffic data needs, such as turning movements, hourly volumes, directional traffic, distributions, and vehicle classifications (categories 5 through 8). Category 9 concentrates on procedures which use these traffic data to produce speed, delay, and queuing information for input to environmental models and capacity analyses. The final set of procedures (category 10) produce appropriate data for highway pavement design.

Once an inventory of existing procedures had been prepared, as discussed above, an evaluation process was used to select the most appropriate procedures. In order to accomplish this task, a basic list of evaluation criteria was developed.

These criteria were based on the following considerations:

- In what circumstances can the procedure be effectively used?
- Is the procedure logical and sensible?
- Are the procedure's underlying assumptions and mechanics intuitively correct?
- Is the procedure sensitive to the critical variables which determine the values of the traffic data?
- What is the relative accuracy of the procedure?
- What is the general availability of required data inputs?
- What are the time and cost requirements for obtaining the required input data and for applying the procedure?
- Is the procedure easy to use? Is it understandable, or is it effectively a black box to its user?
- How easy is it to make errors with the procedure?
- Can the results be easily checked for reasonableness?
- Has the procedure been adequately documented and field tested? If not, what is required in terms of documentation and field testing?
- Have special problems been identified with the procedure?

Table 1. Categorization of procedures.

Category	Procedure
1	Procedures to refine computerized traffic volume forecasts
2	Procedures to derive traffic data for alternative network assumptions
3	Procedures to derive traffic data for more detailed networks
4	Procedures to derive traffic data for different forecast years
5	Procedures to derive turning movement data
6	Procedures to determine design hour volume and other time-of-day data
7	Procedures to derive directional distribution data
8	Procedures to determine vehicle classification data
9	Procedures to calculate speed, delay, and queuing data
10	Procedures to produce traffic data for highway pavement design

It was necessary that existing alternative procedures be evaluated within the context of the data requirements for each of a number of specific types of projects and for varying conditions of data and systems-level forecast availability. For example, a procedure that would be evaluated as "poor" under the condition in which detailed computer travel demand analysis information is available for each alternative might be the best procedure available to develop certain traffic data when only a single systems-level computer forecast is available. Therefore, each alternative procedure was assessed within the context of different scenarios.

These scenarios were defined along several dimensions, as follows:

1. Type of project:
  - Construction of a new freeway or major arterial through a corridor.
  - Upgrading an existing highway facility.
  - Localized roadway improvements.
  - Transportation system management alternatives.
2. Amount of computerized forecast data available:
  - Detailed, high quality forecasts are available for each alternative being studied.
  - Sketch planning level forecasts are available for each alternative being studied.
  - A single systems-level forecast is available.
  - The computerized forecasts either lack enough detail or are nonexistent in the corridor under study.

### 3. Time and budget available:

- Adequate budget, relatively long time available for analysis.
- Small budget and/or short time available for analysis.

During the application of this evaluation process, it was soon found that many of the categories in Table 1 had few or no alternative procedures identified. As a result, procedures for these categories had to be developed or synthesized. Some categories had only one procedure identified in the inventory, and as a result no comparative evaluation of alternatives was necessary prior to recommendations.

In virtually all cases, a detailed comparative evaluation of alternatives was not found to be necessary although the available procedures were still rated for each of the criteria. This rating highlighted the strengths, weaknesses, and key aspects of a recommended procedure, thereby providing significant information for the user's manual. In some instances, identified alternatives were clearly inferior and were eliminated. In other instances, more than one alternative was recommended, as each was more applicable than the other under the different scenarios of data availability, analysis time and cost limitations, and specific characteristics of the highway project under analysis. And finally, in some instances it was concluded that the best elements of each of the identified alternatives should be combined into a new procedure. The primary findings relating to the alternative and recommended procedures in each of the 10 categories are discussed in the remainder of this chapter. The details of each procedure are presented in the user's manual.

### Category 1 — Procedures to Refine Computerized Traffic Volume Forecasts

The procedures in this category are aimed at refining link volumes. The available techniques ranged from simplified single-page guidelines to complex screenline adjustments (46, 88). Virtually all of them involved considerable professional judgment in determining how traffic should be adjusted between facilities. Most procedures look at a network of street assignments, while some are applied only on a link-by-link basis. One commonality of the reviewed procedures seemed to be the explicit or implicit consideration of base year traffic counts, land-use patterns, and traffic growth patterns in the refinement procedures. The level of documentation in this category was fair to good.

One link refinement procedure recommended is an adaption of a methodology developed by JHK & Associates for the Maryland Department of Transportation (46). This procedure includes an overall check of the computer assignments followed by traffic refinement at the link level. A comparison is made between the base year and future year volumes and capacities across a screenline to arrive at a refined assignment. The procedure is modified by embedding within it a methodology developed by the New York State Department of Transportation (77). This technique adjusts for discrepancies between the base year traffic forecasts and actual base year traffic counts. The procedure is most applicable for performing corridor-level analyses.

A second procedure, select link analysis (104, 115), is recommended for refining link volumes within a small study area or for defining travel patterns for reassignment of traffic in over-capacity conditions. A companion method using zonal tree analysis (104, 115) is also

recommended for these applications.

### Category 2 — Procedures to Derive Traffic Data for Alternative Network Assumptions

There are four basic situations to consider in this category: (1) change in roadway capacity, (2) change in roadway alignment, (3) construction of parallel roadways, and (4) addition or subtraction of links.

Since most agencies surveyed rerun a computer model for each network change, there were very few documented procedures. The most sophisticated techniques used are the "windowing" or "focussing" procedures described in Category 3. These procedures enable several alternative networks to be quickly analyzed using a computer.

In other cases, the general trend has been to judgmentally redistribute volumes from parallel links onto a new or modified facility. In the first situation, a modified screenline refinement procedure from Category 1 is suggested for use. This procedure can account for relative changes in roadway capacity, as long as total screenline trips remain constant. Guidelines developed by the State of Washington (119) provided a good basis for the development of a manual procedure, although more specific explanations were required.

The latter three situations require a more rigorous analysis of travel patterns using select link or similar data. Once this is done the screenline procedure from Category 1 can be used to further smooth the volumes across a screenline. Another procedure that is suggested is essentially a manual reassignment process using modified travel times (user-supplied) and the NCHRP Report 187 assignment method (88). Therefore, the procedures developed in this category utilized a combination of computer and manual techniques to produce alternative network assignments in an efficient manner.

### Category 3 — Procedures to Develop Traffic Data for More Detailed Networks

The two primary approaches documented in this category involved either subarea focussing or subarea windowing. In focussing, a more detailed network is defined within the study area, leaving the remaining network intact. In windowing, a more detailed study area network is defined within a cordon. The remaining network is then replaced by a series of external stations.

Each of the procedures involves the use of computer models. Subarea focussing is presented as a computer-aided method based on the documentation of the North Central Texas Council of Governments and Maricopa Association of Governments, among others (75, 61). Subarea windowing is documented in greater detail, emphasizing the process used to conduct either a manual or computer-aided procedure (76). The UMTA and FHWA programs NAG and DONUT provide the base for several expanded windowing procedures used in certain urban areas (115, 104). The experiences of the Minnesota and Ohio Departments of Transportation were used as prototypes (76). There was a divergence of opinion among agencies between focussing versus windowing procedures, but generally the approach has been to detail the study area network prior to running any model. No fully manual procedures were documented.

Less rigorous and computationally and data intensive techniques were also developed. These techniques concentrate on modifying the screenline and select link procedures from Category 1 to reallocate trips based on relative base year and future year volumes, capacities,

and/or travel patterns. All of the above procedures can be considered in conjunction with one another.

#### Category 4 — Procedures to Derive Traffic Volumes for Different Forecast Years

The appropriate procedures in this category depend on the availability of historical traffic count data and adequate land-use or demographic data for the target year for which a traffic forecast is desired. Where these data are available, the suggested procedure is to interpolate or extrapolate the target year trips using a linear or nonlinear method. This decision would depend on the uniformity of expected growth inside and/or outside of the study area. Where full build-out growth data are also available, the rate of growth for an extrapolated year can be modified based on how close the study area is to its development capacity, as discussed by Memmott and Buffington (66).

Where land-use data are unavailable or inadequate, the suggested procedure is to extrapolate (linear or nonlinear) to a target year based on historical traffic and/or demographic trends. This procedure is usually only valid for short time frames.

For more detailed analyses in areas where wide variation in zonal growth are expected to occur, it is recommended that select link and zonal tree data (104, 115) be reviewed for changes in travel patterns and growth on specific facilities. This incorporates a procedure used by the Maricopa Association of Governments (60, 61). The target year assignments are then made on a facility-by-facility basis by interpolating or extrapolating these trends.

#### Category 5 — Procedures to Derive Turning Movement Data

There are three sets of procedures recommended for this category: factoring procedures, iterative procedures, and "T" intersection procedures. None were documented in the literature or in the field. The factoring procedure is a simple factoring of future year turning movements based on the degree of discrepancy between the base year counts and forecasts. Both a "ratio" and a "difference" factor are presented.

Iterative procedures have been developed for situations in which either "directional" or "nondirectional" volume data are available. The directional method is based on a row and column matrix balancing procedure developed by Mekky (64). This method can be applied to most intersection situations; however, it requires a realistic initial estimate of turning percentages in order to produce a final set of turns within a reasonable number of iterations. A related noniterative mathematical model developed by Norman and Harding (73) was found to provide some realistic solutions; however, its applicability was limited to selected intersection conditions and its calculations, while noniterative, were mathematically complex. Therefore, it was not included in the user's manual.

The nondirectional iterative method is a modification of a procedure prepared by the Middle Rio Grande Council of Governments (63). This procedure assumes that intersection link volumes are surrogates for downstream land-use productions and attractions. Its major limitations are a heavy reliance on professional judgment and a lack of a theoretical base. It is therefore most useful for sketch-planning purposes.

Finally, a special procedure for "T" or 3-legged intersections is presented. Because of the simplicity of turning movements in this situation, nondirectional turns can be directly calculated using an equation; directional turns can also be estimated by comparing relationships among various approach link volumes.

#### Category 6 — Procedures to Determine Design Hour Volume and Other Time-of-Day Data

Most of the available procedures in this category involved an analysis of local or statewide data for different time periods. Tables classifying the diurnal or time-of-day data by trip purpose, mode, or other categories were then constructed using these data. Several sources attempted to establish statistical correlations within the classification tables, so that the time-of-day curves could be readily transferred to other locations. One procedure included regression equations that related time-of-day information in Milwaukee to several trip-making characteristics (3). However, these equations were not statistically significant for transfer to other urban areas.

Procedures for forecasting design hour volume, hourly volumes over an average weekday, and peak hour factors have been recommended. With respect to design hour volume, different procedures were developed for those typical urban facilities with peaks defined by work travel and for those atypical urban facilities with peaks defined by recreational travel (6). For typical urban highway facilities whose peaks are determined by work travel, transfer of known design hour volume/average daily traffic ratios were recommended based on comparable highway type, location, orientation, adjacent land use, and level of service (6, 70). For urban facilities whose peaks are determined by recreational travel, the procedures recommended involved the transfer of base year known design hour volume/average daily traffic ratios from facilities that operate in a manner similar to how the facility under analysis is expected to operate in the future.

Procedures for weekday hourly volume forecasting were similarly based on transferring known hourly volume proportions based on several facility characteristics (88). Peak hour factor forecasting procedures were dependent on the availability of base year data and ranged from use of base year factors on similar facilities to the use of areawide peak hour factors.

No transferable documentation was found describing procedures for adjusting time-of-day curves based on the level of congestion on a facility or in a subarea or corridor. One study developed relationships between traffic level of service and the percentage of daily traffic in order to produce an estimate of the duration which congested conditions occurred within a study area. Unfortunately, the relationships were specific to local areas and required data on daily travel stratified by level of service ranges. Therefore, its applicability became severely limited. This is an area for further research.

#### Category 7 — Procedures to Derive Directional Distribution Data

The procedures in this category try to establish relationships between directional distribution and various factors, such as time-of-day, facility type, and orientation (i.e., radial, circumferential). The efforts to establish the statistical significance of these relationships have not been very successful. In lieu of these data, other procedures basically begin with a base year directional split (e.g., 60-40) and then make manual adjustments for future years using professional judgment and knowledge of abutting land uses (e.g., commercial, residential, industrial).

Two procedures to forecast peak hour traffic directional distribution were recommended. The first procedure, developed for the Maryland State Highway Administration by JHK & Associates, consists of the modification of base year directional distributions of peak hour traffic. The modification is based on a comparison of base year and future year work purpose traffic directional distribution in the facility corridor. One way

to conduct this comparison is to perform traffic assignments of work purpose traffic in a production-attraction format for both the base year and future year. A less data-intensive, but more judgmental way to conduct this analysis is through a comparison of total base year and future year work trip (or residential trip) productions and attractions in the corridor.

The second procedure involves the transfer of peak hour directional distribution factors from facilities which today have characteristics like those envisioned in the future for the facility under analysis (88). The key characteristics that should be considered in such a transfer are highway type, location, orientation, and land use.

#### Category 8 — Procedures to Determine Vehicle Classification Data

Vehicle classification data usually consist of the percentage of total traffic that is comprised of light, medium, and heavy vehicles. Of these, the heavier truck classifications are the key variables to consider for highway design and environmental studies. The typical procedure used to determine vehicle classification data has been to assume that the base year vehicle classification of traffic on a facility will not change in the future. Similarly, the existing procedures to forecast vehicle classification characteristics are very judgmental and rely on data collected in a specific local area.

The recommended procedure includes an additional step. In this step the land-use changes in the traffic-shed of the facility under analysis are reviewed for the base year and future year. An estimate is then made of the degree of change in the proportion of those land uses in the traffic-shed that are known to generate truck traffic. This information is then used to modify the base year vehicle classification data. Similar relationships could not be established between vehicle classifications and such factors as time-of-day, facility type, and orientation of the facility. This is an area for further research.

#### Category 9 — Procedures to Calculate Speed, Delay, and Queuing Data

Various procedures were investigated to calculate speed, delay, and queuing data on grade-separated facilities and surface arterials. It was found that separate procedures were applicable for under-capacity and over-capacity conditions, a key distinction to be made in several environmental models. The characteristics of grade-separated facilities and surface arterials differ considerably because of the impacts of traffic signals and other controls for at-grade intersections.

The existing speed calculation procedures all involve a relationship between operating or average speeds, and the level of service or volume-to-capacity ratios on a facility. A series of curves have been developed in several studies (38, 45, 90) and in some computer software documentation (104, 115).

None of the available procedures adequately address the sensitivity of traffic speeds close to bottlenecks or to intersections. This sensitivity can be especially important in air quality and energy modeling. The procedures also differ in the calculation of speeds in over-capacity conditions.

The primary interest of delay and queuing procedures is at intersections where queuing can affect design needs (e.g., length of turn lanes) and localized environmental conditions (e.g., carbon monoxide hotspots). Several theoretical equations are available in the literature for modeling under-capacity conditions (120, 124). A deterministic procedure using various worksheets was provided in NCHRP Report 133 (91). In oversaturated conditions, fewer documented procedures were available. Linear models were reviewed from various sources (91,

104).

The recommended procedures combine the most relevant and straightforward techniques to calculate speeds, delay, and queuing. For under-capacity conditions on grade-separated facilities, the speed procedure uses a curve developed as part of the interim capacity materials of TRB Circular 212 (46). It is recommended that arterial speeds be determined through procedures documented in A Manual on User Benefit Analysis of Highway and Bus Transit Improvements published by AASHTO (90) and procedures documented in Signal Operations Analysis Package (SOAP) published by USDOT/FHWA (112). The arterial speed forecasting procedure combines relationships between mid-block average running speed and volume-to-capacity ratios with forecasts of intersection delays.

Procedures to calculate delay and queue lengths for under-capacity conditions are only applicable to surface arterials. The recommended procedure is based on Webster's equations (120) and is similar to the technique contained in the above referenced AASHTO Manual (90).

The procedures proposed for speed, delay, and queuing calculations for over-capacity conditions are those contained in NCHRP Report No. 133 (91). The procedure for grade-separated facility speed and queue length forecasts is based on a shock-wave method of queuing analysis. The procedure for surface arterial speed, delay, and queue length forecasts is based on a deterministic method of queuing analysis.

#### Category 10 — Procedures to Produce Traffic Data for Highway Pavement Design

The procedures most commonly used and recommended are those in the AASHTO Interim Guide for Design of Pavement Structures (5). The procedure involves the conversion of traffic data to 18-kip (18,000-lb) equivalents based on the forecast vehicle classification on the facility and statewide or station-specific rates of 18-kip equivalent single-axle loadings per 1,000 trucks. The 18-kip equivalent truck factors are then applied to each classification of vehicle in order to obtain a composite value for design purposes. Therefore, the time-of-day, directional distribution, and vehicle classification data obtained from procedures in Categories 6, 7, and 8 are directly used in this methodology. Some state agencies have computerized a similar version of the AASHTO 18-kip procedure, although most surveyed locations still use manual computations.

#### SUMMARY

This chapter has presented the major findings of the research study. A literature search, followed by the distribution of a questionnaire to several public agencies provided background on existing practices in producing highway traffic data in the United States. It was found that most agencies conduct regular base year traffic counting programs but do not have standardized procedures for forecasting traffic data for future year conditions.

The questionnaire results and subsequent personal and telephone interviews confirmed many of the insufficiencies in the traffic forecasting process. These include a lack of documentation of transferable procedures that can be applied in various situations, a lack of standardized formats for requesting and displaying traffic data for different applications, and the inability of current forecasting efforts to consistently produce realistic traffic data for various highway alternatives.

It was found that many traffic forecasting activities are performed using a vast amount of professional judgment with minimal reliance on any standardized procedures. As a result, documentation of procedures was

incomplete or totally lacking in several of the traffic forecasting categories investigated in this study. Heavy emphasis, therefore, was placed on synthesizing portions of existing procedures and developing new procedures in response to the needs identified by practicing traffic analysts.

The procedures summarized in this chapter and fully described in the user's manual included in the Appendix to this report cover a total of 10 categories. These include traffic refinement and detailing procedures, procedures to

produce specific traffic data needs (e.g., turning movements, hourly volumes, directional traffic distributions, and vehicle classifications), and procedures that use these data for environmental and highway design purposes. Various situations commonly encountered by the traffic analyst are addressed using examples and case studies wherever possible. The product of this effort is a manual of procedures that can be used to supplement, but certainly not replace, many traffic forecasts currently conducted using judgment alone.

## CHAPTER 3

# INTERPRETATION, APPRAISAL, AND APPLICATION

This chapter presents an interpretation and appraisal of the key issues and technical procedures involved in forecasting traffic data for highway project planning and design. Following this discussion suggestions are made for the application of these findings to current and future traffic forecasting efforts.

## INTERPRETATION AND APPRAISAL

The major focus of this project was the examination of procedures for producing traffic data for use in highway planning and design activities. In the preceding two chapters, several findings were examined with regard to traffic forecasting issues revealed through the results of a questionnaire, telephone contacts, and personal interviews held with public agency staffs throughout the country. In addition, various procedures were identified and evaluated. These aspects of the study are explored more fully in terms of their meaning to practicing traffic analysts and their implications for needed improvements.

### Development of Traffic Data

The study findings clearly indicate that a large percentage of highway planning and design decisions are based on the results of traffic data forecasts. At the same time, it is apparent that the quality of the input data and the analysis procedures used for these forecasts are viewed as being deficient in many respects. The following discussion focusses on the critical problems faced by the analyst who must develop the traffic data that are used for project planning and design. An understanding of these problems is necessary before the findings of this study can be fully interpreted and appraised.

The level of detail and accuracy of computer traffic forecasts vary tremendously from project to project. In one scenario a computerized travel demand forecast will have been made for each alternative under study using a stochastic capacity-restrained assignment procedure, with a great deal of effort having been expended on fine-tuning the land-use data inputs and defining a detailed highway network. Forecasts will have been made for each future year under study, and turning movements will have been produced for each critical intersection in the study area. In some cases a design hour computer assignment may even be available. In the more common scenario, however, computer forecasts are not available at this level of detail or accuracy or with the amount of fine-tuning of land use and network data that is desirable.

The lack of quality land-use forecasts was cited as a major problem facing the traffic analysts. Frequently, the analyst is required to manually adjust a traffic assignment to compensate for inaccuracies in land-use assumptions both in the base year and the future years. This problem occurs often when forecasts are requested for target years that do not match years for which land-use forecasts have previously been made. In such cases, the available land-use data must be manually interpolated or extrapolated to correspond to the target years. These extra computations and required assumptions can create land-use data errors or inconsistencies. Similarly, when the traffic analyst is performing small area studies, the available land-use data at the district or even zonal level is not accurate enough to produce reliable traffic forecasts on the specific facilities being examined.

The questionnaire results show that many traffic forecasts are still performed with all-or-nothing assignment procedures that assign all trips for a zonal interchange onto the same travel path, even though in reality travelers between the zones will choose a number of different travel paths of approximately equal travel time. The net result is imbalanced loadings on parallel routes. This situation still occurs to a lesser degree in the case of capacity restrained assignments that assign trips on the basis of available roadway capacity. In the majority of cases computer assignments are made using a 24-hour trip table and a systems-level highway network which does not provide the level of detail required for most project planning and design studies. Although capacity restraint procedures will lower the speeds on overloaded links during assignments, minimum travel paths may continue to be built through the overloaded links, thereby resulting in unrealistic assignments with link far exceeding capacities.

Many analysts showed a preference for all-or-nothing assignments, because travel patterns could be more readily traced and adjusted manually. Indeed, some of the procedures described in the user's manual, such as select link and zonal tree analyses, are more straightforward using all-or-nothing assignments. However, with continuing advances in assignment processes and more emphasis being placed on providing better coded highway networks and input data, capacity restrained methods can be expected to provide traffic assignments that will require fewer time-consuming manual refinements.

Due to limits on budgets, time permitted to perform analyses, and staff capabilities, computer assignments are often not available for all alternatives being considered. Many agencies are set up to forecast volumes for only a single year in the future, a year that is often somewhere in between the build year and the design year. At the

present time the design year for most projects in project planning is somewhere between 2005 and 2010, but most agencies are performing systems-level forecasts for only 1995 or 2000.

Because of the cost of running large-scale computerized travel demand forecasts, the analyst on a project planning study must often be content with having a single systems-level traffic assignment with which to work. Network assumptions in the vicinity of the project under study may be different or much less detailed than the network assumptions the analyst has been told to use. Most analyses of alternative network assumptions must be done manually, traditionally through the use of judgmental procedures.

Similar is the case where either no computer forecast is available for use in the analysis or where the network used in the systems-level forecasts simply does not provide enough detail in the vicinity of the project under study. In most urban areas the majority of highway project planning and design studies are in rapidly growing fringe areas where the computer zone system and coded network are very coarse and in many cases even nonexistent. In these cases manual procedures must be relied upon to produce traffic forecasts for use in design and project planning.

Even under a scenario in which detailed computer assignments are produced for each alternative under study for both the build and design year, there is a large amount of additional data which must be developed for input to evaluation, environmental analysis, and design processes. The following is a list of traffic data which are often required in project planning and design studies:

- Average daily traffic volumes by link.
- Design hour traffic volumes by link.
- Turning movements for each intersection approach.
- Levels-of-service (mid-link, intersection, and interchange).
- Capacities (design and maximum).
- Level-of-service C volumes (for input to noise models).
- Diurnal curve (time-of-day) data.
- Vehicle classification data.
- Speed and delay data.
- Queuing data.

In some cases these data are required on all the links of a detailed network in order that the impacts of alternatives on total air pollutant emissions and energy consumption can be determined. Similarly, the impacts of the project on certain parameters such as time-of-day distribution, directional distribution, and vehicle classification characteristics are difficult to predict. As a result, existing patterns are often assumed to remain the same in the future, when in fact the effects of increased congestion levels and development patterns will cause these parameters to change. Guidance is needed on ways to predict changes in these variables. It seems paradoxical that extremely detailed traffic data must be developed for input to project planning and design when the systems-level computer forecasts that are used as a basis for producing these data are often very coarse and prone to error.

The standard computer traffic forecasting process consists of a chain of four separate models (trip generation, trip distribution, modal split, and trip assignment), each of which has inherent errors and biases. In some cases, these errors and biases are offsetting, and reasonable forecasts are generated for the facility being studied. However, in many cases the resulting traffic assignments require substantial refinement. Even validation assignments of base year traffic can be quite inaccurate, although validations are certainly of more benefit to the assignment process than the prevalent situations in which base year validations are not performed. A general rule of thumb for base year

assignments for a particular roadway states that a good assignment has been performed if the assigned volumes are within 20 percent of actual observed volumes. Yet a 20 percent difference in traffic volumes can frequently mean the difference between providing a design level of service and exceeding the maximum capacity of a facility.

The survey results show that the responsibilities for various traffic analyses are fragmented among agencies. The state Departments of Transportation (DOT) provide the majority of these analyses, and in several states these functions are quite centralized. However, some states revealed that many traffic forecasting duties were allocated to the metropolitan planning organizations (MPO's), to district offices of the state DOT and in some cases to local agencies.

The variable role of the MPO's across the country with respect to traffic data development points to a need to better define their responsibilities. Whereas the land use and socioeconomic projections have traditionally been the responsibility of MPO's, the survey results indicate that other MPO roles vary from doing nothing to physically performing traffic counts.

Related to this issue is the observation that a majority of the surveyed agencies did not have any standardized format for requesting traffic data for various uses. The agencies that did use forms stated that this activity definitely reduced misunderstandings between the producers and users of the data. In most cases, the forms were simple one- or two-page requests for specific data to be used for planning, design, or environmental studies.

#### Analysis Procedures

Most transportation analysts have recognized the need to refine computer traffic assignments before submitting traffic projections for use in highway project planning and design. Various procedures are used throughout the nation, with varying levels of sophistication, standardization, and documentation.

The questionnaire results showed that over 50 percent of the responding agencies do not use standardized procedures for producing traffic data. However, there appears to be considerable standardization of procedures for using the resulting data. These procedures include the AASHTO user benefit analysis (90) and highway design methodologies (5, 6), the *Highway Capacity Manual* (38), and a number of environmental models. The primary implication of this disparity is that while public agencies are in partial agreement with respect to techniques for using highway traffic data, they have virtually no uniform procedures to initially develop those data. Thus, results of pavement design or air quality computations in one state cannot be readily compared with results obtained from adjacent states. This problem even manifests itself among urban areas within the same state.

The few standardized procedures currently being used to produce traffic data are typically poorly documented, poorly disseminated, and often only applicable to specific conditions. The documentation problem occurs because traffic analysts are typically not requested to fully document the procedures which they use to develop the traffic data. Documentation is also often performed as an afterthought some time after the analysis is completed, causing the analyst to overlook key details or helpful suggestions. Finally, the person who writes the documentation may not be the same person who performed the analysis. Thus, a very general report may result.

Some of the better documented procedures obtained in this study were retrieved from old project files or from a person's bookshelf. The procedure had often never been distributed outside of the department, much less the agency. This dissemination problem was not intentional in most cases, yet the information has failed to reach many

of the analysts who could most benefit from it.

Many procedures were developed in response to the needs of specific project conditions, and therefore were limited in scope. For instance, regression equations used to forecast time-of-day distributions were typically based on a small set of localized data, and thus were not transferable to other urban areas or conditions. Other procedures were only partially developed to the extent required for use in specific traffic studies; the extra steps required to complete the procedures so that they would become more widely applicable were not undertaken.

The need existed to identify as many of the available procedures as possible, evaluate each of the procedures identified, draw upon the strongest points of the procedures evaluated, and develop a set of standard procedures that could receive national distribution. However, because of the great variance in the type and quality of computer forecasts that are used, and because of differing data requirements for different types of highway projects, it was necessary that a series of procedures be developed from which the analyst could select the most appropriate procedure for the particular study being performed.

The interpretations and appraisals of specific recommended procedures are thoroughly discussed in the user's manual. In terms of categories of procedures (see Table 1), it was apparent that the link-level traffic data refinement and detailing procedures (categories 1 through 4) were the least well documented and offered the greatest opportunity for variations among analysts. Typically the analyst is confronted with the need to convert a systems-level traffic forecast to some more detailed forecast within the immediate area of a proposed highway improvement. Several assumptions are required to perform such conversions. Therefore, the analyst must use a considerable amount of professional knowledge and judgment to apply even the most "standardized" procedures.

Because so many situations can occur which render any "cookbook" procedure useless, many analysts have resorted to using pure judgment for making such refinements. As a result, few documented procedures exist. The attempt in this research study was to combine the few available procedures with comments offered verbally by practicing analysts.

The second grouping of categories (categories 5 through 8 in Table 1) relates to procedures used to produce specific traffic data items, such as turning movements, hourly and directional distributions, and vehicle classifications. These procedures were somewhat better documented, possibly because they focussed more on data that could be obtained using mathematical computations rather than using pure judgment. Even so, several basic assumptions are required on the part of the analyst, such as whether or not traffic conditions in a future year would be expected to change significantly from those in the base year. Procedures to adjust for changing conditions were not readily available.

The final grouping of categories (categories 9 and 10 in Table 1) included procedures for translating the basic traffic data into inputs for evaluation, environmental, and design analyses. Procedures for computing speeds, delays, and queuing were readily available in the literature; however, the effects of over-capacity highway conditions on these variables were rarely examined. It was apparent that most analyses do not adequately represent traffic flow on congested facilities, a situation that is becoming increasingly familiar in urban areas. The highway design procedures were straightforward and related well to other procedures used to generate the input data. One realization was that the vehicle classification data required for the AASHTO pavement design procedure (5) are considerably more detailed and in a different format than data typically prepared for highway planning and environmental studies. Therefore, special care was taken to explain these characteristics in the procedure.

## APPLICATION OF FINDINGS

The findings presented in this report and in the user's manual are of use to persons engaged in producing and using highway traffic data, such as transportation planners, traffic engineers, environmental analysts, and highway designers in federal, state, regional, and local agencies. Others who will derive benefits from these findings include persons engaged in safety studies, structural design, right-of-way acquisition, geotechnical and materials analysis, maintenance, and financial analysis. Outside of public agencies, land developers, consultants, and citizen groups will also find portions of these findings to be of use.

The findings of the study questionnaire and agency interviews provide an understanding of the strengths and weaknesses of current practices used in the traffic analysis field. Agencies can benefit from the organization and processes established by others to more efficiently perform these studies.

The procedures presented in the user's manual are applicable over a wide range of analyses. The principal types of applications include systems planning, corridor or subarea studies, evaluation of alternative plans, traffic operations studies, highway design, and environmental studies. In order to demonstrate some of this applicability, the procedures were applied to three case examples based on actual studies—a project planning study involving the upgrading of a freeway; a detailed subarea study involving the upgrading of an arterial facility; and a highway design study for constructing an interchange where two major arterial streets intersect. These illustrative examples show the types of procedures that can be applied as well as the level of judgment that is typically required. In all cases, emphasis has been placed on developing manual procedures, although the applicability of several techniques is enhanced with the aid of computer methods.

The procedures for refining systems-level traffic assignments (category 1 of Table 1) are applicable in corridor or subarea settings whether or not base year data are available. An adaptation to handle over-capacity conditions is also provided.

The material relating to alternative network assumptions (category 2) can be used to analyze changes in roadway capacity, changes in roadway alignment, construction of parallel roadways, or the addition or subtraction of network links. These situations occur in various combinations in most traffic analysis studies.

The windowing and focussing procedures for analyzing detailed highway networks (category 3) represent computer-aided approaches. Both are most applicable for small scale corridor or subarea studies in which detailed link and turning traffic volumes are desired on various highways that are not shown on a systems-level network. Simplified approaches are also described that are more applicable for quick-response studies.

Often the analyst is faced with the need to provide traffic data for study years for which no computer forecasts are available. Materials are presented (category 4) which permit available forecasts to be modified based on expected changes in land-use patterns. The procedures are flexible to permit an analyst to select between linear and nonlinear growth rates to be applied on a zonal or subarea corridor level. Treatment is also given to situations where development is approaching the full-buildout level.

The turning movement procedures (category 5) can be used to develop directional or nondirectional (i.e., two-way) turning volumes given various types of link volume data. Therefore, the analyst can use a systematic approach to estimate intersection turns for use in planning or design studies.

Design hour volumes (category 6) are the key data to produce for many traffic studies. Procedures are

documented to permit design hour volumes to be determined for typical urban facilities and for facilities characterized by sharp recreational or seasonal variations. Other time-of-day procedures are useful to convert daily volume estimates to hourly data for use in design or environmental studies.

The procedures for determining directional distributions (category 7) are most applicable in design studies requiring estimates of peak direction traffic flows. They can also be of use in analyzing other transportation systems management actions, such as reserved bus and carpool lanes or reversible flow lanes.

The vehicle classification procedure (category 8) provides basic background relevant to the estimation of various auto-truck percentages on urban facilities. These data, in various formats, are key inputs to the calculation of highway design needs and to the determination of environmental impacts, including air quality, noise and energy consumption.

Procedures are presented for calculating speeds, delays, and queue lengths (category 9) on grade-separated facilities and on surface arterials. The analyst is able to apply different methodologies for traffic flow conditions that are under- or over-capacity. The resulting data are directly applicable to small area design analyses, such as the determination of turning lane length requirements, and to environmental analyses.

Highway pavement design (category 10) is a critical

area for which specific traffic data are required. The procedures presented enable traffic volume and vehicle classification data to be converted into 18-kip equivalent single-axle loadings, which are directly used in the calculation of flexible and rigid pavement design needs. These procedures are applicable using vehicle classification data, specific to the subject facility or average values obtained on a regional or statewide basis.

Generally, the procedures contained in the user's manual can be applied whether the system level traffic assignments have been produced through a computerized or manual process. Although the majority of applications would likely be in conjunction with a conventional UTPS traffic assignment, the procedure could also be used with assignments produced through manual or quick-response procedures, such as those contained in NCHRP Report 187 (88).

In summary, the findings provided in this report and in the user's manual have been shown to be appropriate for several types of applications. It is anticipated that some or all of the recommended procedures would be adopted by various agencies and personnel. The procedures presented are state of the art and are suggested to provide the traffic analyst the best analytical base for traffic estimates. It is expected that as the procedures receive widespread use, additional applications and suggested revisions or improvements will become apparent.

## CHAPTER 4

# CONCLUSIONS, SUGGESTED RESEARCH, AND RECOMMENDATIONS

## CONCLUSIONS

The following general conclusions are presented based on the findings of the research:

1. Traffic data are used for three primary purposes in highway project planning and design in the United States: (a) for evaluation of alternative highway improvement projects; (b) for input to air quality, noise, and energy analyses of highway improvement projects; (c) for input to capacity and pavement design analyses.

2. The traffic data that are produced by systems-level computerized traffic assignment procedures must, in virtually all cases, be refined and subjected to further analysis in order that traffic data can be produced which can be used for highway project planning and design.

3. To date there has been virtually no national standardization of procedures for the development of traffic data that are used as input to evaluation, environmental, and design analyses. As a result, there are wide variations in the format and quality of traffic data produced by agencies.

4. Travel behavior is determined by a complex combination of a large number of factors. In response, the mathematical models used to forecast travel demand must make a number of simplifying assumptions and cannot take into account factors that are sometimes very important in determining travel behavior. As a result, traffic forecasts, particularly for individual facilities within a systems-level forecast, can vary significantly from actual observations.

Procedures to refine systems-level forecasts for use at the facility level are documented in the user's manual. It

is critical that the user of these procedures realize that they are merely mechanisms to overcome some of the inability of the computer models to exactly replicate travel behavior. These procedures must be applied with considerable judgment and should only be applied after the analyst understands how the procedures work.

5. The procedures documented in the user's manual are designed to be used to produce facility-oriented data. Their applicability to larger sub-area studies is limited by difficulties in getting all routes in all directions to balance. Other new and emerging techniques, such as MICRO and TRAFFLO, should be considered when performing sub-area, rather than facility-oriented studies.

6. The procedures contained in the user's manual should be applied only after computer forecasts have been produced which pass a number of reasonableness tests. The types of checks that should be made and degree of accuracy required of the computer forecasts are documented in Chapter Three of the user's manual.

Special emphasis needs to be placed on ensuring the accuracy of land-use (socioeconomic) input data and coded network data. The majority of problems with systems-level forecast data used for highway project planning and design studies can be traced to problems with these data.

7. Production of adequate traffic data requires considerable effort and time as well as judgment that comes with experience. It is critical that agencies devote the time and effort necessary to produce a high quality forecast, because planning and design decisions that can raise or lower the cost of a highway project by millions of

dollars are often based on traffic data.

8. A large number of explicit and implicit assumptions are made every time traffic forecasts are performed for highway project planning and design studies. For instance, too often future traffic volumes have been forecasted using the assumption that existing or base year conditions will not change. Preliminary research in this study indicates that this assumption is not valid in many situations, especially in fast-growing suburban and rural areas. Therefore, it is important that both the producers and users of traffic data fully understand the sensitivity of the analyses to these assumptions and the implications of making alternative assumptions.

9. It is important that the producers of traffic data have a general understanding of how the traffic data are to be used to ensure that the proper data are prepared. Serious errors have often been caused in subsequent environmental or design analyses because of definitional misunderstandings about what data were required.

10. The users of the traffic data must understand the limitations and degree of uncertainty associated with traffic forecast data. Evaluation, environmental, and design analyses all require extremely detailed traffic data as input. These data often influence important decisions; therefore, it is important that the use of traffic data as input to these decisions be tempered by the degree of uncertainty associated with the forecasting process.

## SUGGESTED RESEARCH

The following areas of research are suggested based on the results of this project:

1. The effects of over-capacity conditions on highways should be examined with respect to future land-use development as well as to the temporal and geographic distribution of traffic. It is apparent from this research that insufficient data currently exist to determine what dampening effects recurring congestion will have on future land-use growth in a corridor or subarea. These effects will influence the magnitude and shape of growth curves used to interpolate or extrapolate traffic volumes to alternate study years. Similarly, the extent to which congestion causes motorists to divert to alternative routes or to change the time at which the trip is made (e.g., "spreading of the peaks") is an important factor to examine further.

Future research could also include assessments of trip generation and trip distribution changes that occur as the result of various network modifications. For instance, the addition of a parallel facility in a corridor would likely influence the interzonal distribution of work and nonwork trips. A temporal shift in trip generation could also occur. The magnitude of these effects should be carefully determined.

2. Many of the manual computational procedures presented in the user's manual could be adapted to hand-held calculator or especially to microcomputer applications. For example, the repetitive screenline refinement calculations in Chapter 4 of the user's manual could be readily performed in much less time and with greater accuracy using a microcomputer. Additional screenlines could also be examined in an efficient manner. Other calculations such as those in the iterative turning movement procedure, in the speed, delay, and queue length procedures, and the manual assignment procedure are also candidates for microcomputer or calculator applications.

3. The windowing and focussing procedures presented in the user's manual would be enhanced by providing additional examples of their applications to various subarea network situations. The directional subzoning technique presented as a windowing option should also be applied to several network configurations in order to determine its maximum usefulness to traffic analysts.

4. The traffic growth curves developed for adjusting

forecasted volumes to alternate study years are influenced by various factors, including land-use development trends, timing of development and highway improvements, and level of congestion (discussed previously). There is a need to better quantify these factors such that transferable parameters that influence traffic growth can be developed. The need is particularly acute to develop means to adjust traffic volumes in the vicinity of zones that are expected to have wide variations in expected growth. Such research should focus on specific effects on externally and internally generated traffic. If reasonable transferable parameters can be developed, the need to produce additional computer forecasts will be reduced.

5. The turning movement procedures require additional research to derive nondirectional and directional turns from nondirectional link volumes. This research would require more explicit accounting of land-use changes, roadway geometric modifications, and the development of transferable data for various facility types (e.g., freeways, arterials), locations (e.g., CBD, fringe suburban), and geographic orientation (e.g., radial, circumferential). These data would better systematize much of the judgment currently utilized in the procedures.

A noniterative procedure to derive directional turning volumes (73) should be further researched to increase its applicability and to simplify its calculations. Such a procedure, properly mechanized in a microcomputer or calculator, could enable reasonable turning movements to be derived in a more efficient manner than the iterative procedures.

6. Improved data and statistics are needed to transfer time-of-day, design hour volume, directional distribution, and vehicle classification data to other roadway types, to other geographic settings, and to future year scenarios. In the future year situation, techniques should be researched to adjust these relationships based on changes in land use, demographic data (e.g., employment, population, households), or expected roadway congestion. These data will increase the accuracy of future year traffic volumes used as key inputs for evaluation, design, and environmental studies. This research could build on data contained in the report An Analysis of Urban Travel By Time of Day (93).

7. Improved time-of-day data are required to relate design hour volumes to the average weekday peak hour and to establish truck hourly percentages throughout the day. The design hour volume (DHV) has often been substituted by the average weekday peak hour (AWPH) in performing traffic and design analyses. Although generally accepted for use by traffic and design analysts, the AWPB in several cases is not equivalent to the 30th highest annual hour. The magnitude of these differences and their implications on highway evaluation and design should be closely examined.

Similarly, improved time-of-day truck distributions are necessary. Current data do not accurately reflect the variations of truck volumes that occur during off-peak hours. Because several air quality and noise analyses often require detailed off-peak hour data for all highway modes, the inaccuracies in hourly truck volume estimation bias these results. Truck volume data in various categories (e.g., light, medium, heavy-gas, heavy-diesel) should be assembled over several time periods on facilities of different type, location, and orientation to major activity centers.

8. Improved relationships should be developed between various highway speed groups, such as design speed, operating speed, average speed, and average running speed. These relationships are important since current evaluation, design, and environmental models each require different speed data. One additional step may be to incorporate other factors besides the volume-to-capacity ratio into speed curves and equations. Such factors as land-use development, specific roadway

geometrics (e.g., lane widths, sight distance), and traffic signal characteristics (e.g., cycle length, phasing, progression) should be more explicitly considered in estimating speeds on different facility types.

9. Research should be conducted to better relate typical vehicle classification counts performed by agencies to truck loadometer station data required for highway pavement design. The research would establish statistical distributions of truck axle loadings for various truck types, highway types, geographic locations, and orientations to major activity centers. These transferable data would reduce the need to perform classification counts and investigate specific loadometer station data for each facility being analyzed.

Similarly, better means should be established to estimate truck classifications for each year of the highway design life, rather than assume that the annual truck rate will remain constant over that period. Providing this extra level of detail may improve the accuracy of the design calculations and increase the probability that the pavement will be properly designed.

10. All of the environmental models examined would benefit by better specificity and often simplicity of traffic data needs. The documentation should clearly distinguish between the types of traffic volumes (e.g., peak hour, 24 hour), speeds (e.g., average running speed,

operating speed), and vehicle classifications (e.g., light, medium, and heavy trucks; motorcycles, etc.) which are required for application. Additional efforts should focus on standardizing and, if possible, reducing the traffic data needs for various air quality, energy, and noise models, as well as for currently used evaluation models. A common traffic data base for most models would improve the ability of the traffic analyst to produce quality data in a timely manner, and would improve the comparability of results.

## RECOMMENDATIONS

This research project represents the first major effort to document standardized procedures for producing traffic data for use in project planning and design. It is critical that an effort is made to disseminate this documentation to both the producers and users of highway traffic data throughout the United States.

It is recommended that a training course be developed to facilitate the transfer of information contained in this report. At the same time, the U. S. Department of Transportation should make efforts to ensure that standardized procedures for developing traffic data are used on highway projects involving federal funding.

## REFERENCES AND BIBLIOGRAPHY

1. Abrams, C. M. and DiRenzo, J. F., "Development and Evaluation of TSM Strategies." Measures of Effectiveness for Multimodal Urban Traffic Management. JHK & Assoc. and Peat, Marwick, Mitchell & Co., prepared for Dept. of Transp., Federal Highway Admin., Washington, D. C. (Dec. 1979).
2. Agent, K. R., Evaluation of the FHWA Highway Traffic Noise Prediction Procedure SNAP I. Kentucky Bureau of Highways, prepared for U. S. Dept. of Transp., Federal Highway Admin., Washington, D. C. (Jan. 1980).
3. Ahmad, A. K., "Peak Period Urban Traffic Estimation." Masters Thesis, Center for Urban Transportation Studies, The University of Wisconsin-Milwaukee (Aug. 1981).
4. Alfa, A. S., "Time-Dependent Route Assignment of Peak Traffic." Transportation Engineering Journal, Vol. 107. American Society of Civil Engineers (Mar. 1981) pp. 153-163.
5. American Assn. of State Highway and Transp. Officials, AASHTO Interim Guide for Design of Pavement Structures 1972 (Revised). Washington, D. C. (1981).
6. American Assn. of State Highway and Transp. Officials, "A Policy on Geometric Design of Highways and Streets" (Review Draft No. 2). NCHRP Project 20-7 (1979).
7. Bacharach, M., "Biproportional Matrices and Input-Output Change." Cambridge University Press (1970).
8. Baerwald, J. E. (ed.), ITE Transportation and Traffic Engineering Handbook. Prentice-Hall, Inc. (1976).
9. Bailey, M. J., "Estimation of Design Hour Volume." ITE Journal. Washington, D.C. (Aug. 1981) pp. 50-55.
10. Barry, T. M. and Reagan, J. A., FHWA Highway Traffic Noise Prediction Method. U. S. Dept. of Transp., Federal Highway Admin., Washington, D. C. (Dec. 1978).
11. Barton-Aschman Assoc., Inc. and R. H. Pratt & Co. Division, Traveler Response to Transportation System Changes. Prepared for U. S. Dept. of Transp., Washington, D. C., 2nd edition (July 1981) & 1st edition (Feb. 1977).
12. Benson, P. E., Caline 3 - A Versatile Dispersion Model for Predicting Air Pollutant Levels Near Highways and Arterial Streets. California Dept. of Transp. (Nov. 1979).
13. Berman, N. et al., Trips in Motion: Methodology and Factors for Estimating Hourly Traffic Volumes from Average Daily Traffic. CALTRANS/LARTS (Sept. 1975).
14. Bowlby, W., SNAP 1.1: A Revised Program and User's Manual for FHWA Level Noise Prediction Computer Program. U.S. Dept. of Transp., Federal Highway Admin., Washington, D.C. (Dec. 1980).
15. California Dept. of Transp., Noise Manual. CALTRANS (n.d.).
16. Christiansen, D. L., Urban Transportation Planning for Goods and Services - A Reference Guide. Texas A & M University, prepared for Dept. of Transp., Federal Highway Admin., Washington, D.C. (June 1979).
17. Cohen, G. S. and Kocis, M. A., "Components of Change in Urban Travel." Research for Transportation Planning, Preliminary Research Report No. 159. New York State Dept. of Transp., Albany, N.Y. (July 1979).
18. Corns Corp., Traffic Assignment. U. S. Dept. of Transp., Federal Highway Admin., Washington, D.C. (Aug. 1973).
19. Connecticut Dept. of Transp., Traffic Assignment Analysis Techniques. (n.d.).
20. Crowley, K. W. and Habib, P. A., Mobility of People and Goods in the Urban Environment: Facilitation of Urban Goods Movement. Prepared for U. S. Dept. of Transp., Washington, D. C. (Dec. 1975).
21. Curry, D. A. and Anderson, D. G., "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects." NCHRP Report 133 (1972) 127 pp.

22. Darling, E. M., Jr. and Garlitz, J. D., Computer Modeling of Transportation-Generated Air Pollution, State-of-the-Art Survey II. U.S. Dept. of Transp., Washington, D. C. (Mar. 1978).
23. Davis, M. B., "Background and Description." The 1976 Urban and Rural Travel Survey. California Dept. of Transp. (1976) Vol. I.
24. DeLeuw, Cather & Co., Characteristics of Urban Transportation Systems. Prepared for U. S. Dept. of Transp., Washington, D. C. (May 1974).
25. Dunn, S. E., Highway Noise Prediction. Florida Atlantic University, Boca Raton, Florida (n.d.).
26. Erlbaum, N. S., "Procedures for Estimating Energy Consumption in Transportation Projects." Preliminary Research Report No. 174. Research for Transp. Planning, N. Y. State Dept. of Transp. (June 1980).
27. Ferlis, R. A., Guide for Estimating Urban Vehicle Classification and Occupancy. U. S. Dept. of Transp., Federal Highway Admin., Washington, D. C. (Sept 1980).
28. Fisher, R. F., Williams, G. J., and Boyd, P., Atlanta Vehicle Occupancy Monitoring. Georgia Dept. of Transp., Planning Data Services Section and Atlanta Regional Commission (Sept. 1979).
29. Florida Dept. of Transp., Flexible Pavement Design Manual. Div. of Road Operations, Florida Dept. of Transp. (Nov. 1980).
30. Furness, K. P., "Time Function Iteration." Traffic Engineering and Control, Vol. 7:7 (Nov. 1965) pp. 458-460.
31. Gerlough, D. L. and Huber, M. J., "Traffic Flow Theory, A Monograph." TRR Special Report 163, Transp. Research Board (1975) 222 pp.
32. Gordon, G. G., Galloway, W. J., and Kugler, B. A., "Highway Noise: A Design for Highway Engineers." NCHRP Report 117 (1971) 79 pp.
33. Guthman, L. E., User's Guide to MOBILE I: Mobile Source Emissions Model. U. S. Environmental Protection Agency, Washington, D. C. (Aug. 1978).
34. Habib, P. A. and Crowley, K. W., "An Economic Approach to Allocating Curb Space for Urban Goods Movement." Paper for the Transp. Research Board Annual Meeting, TRB, Washington, D.C. (Jan. 1976).
35. Harmelink, D., Estimation of Annual Average Daily Traffic (AADT) and Thirtieth Highest Hour Volume. Ontario Department of Highways (1968).
36. Harrison, D. T. and Ward, T., "Carbon Monoxide 'Hot Spot' Analysis: Providence, Rhode Island." Technical Paper No. 96. Office of State Planning, Providence, R. I. (May 1981).
37. Hartgen, D. T., "What Will Happen to Travel in the Next 20 Years?" Research for Transportation Planning, Preliminary Research Report No. 185. New York State Dept. of Transp., Albany, N.Y. (Aug. 1980).
38. Highway Research Board, "Highway Capacity Manual." HRB Special Report 87 (1965).
39. Huber, M. J., Boutwell, H. B., and Withford, D. K., "Comparative Analysis of Traffic Assignment Techniques With Actual Highway Use." NCHRP Report 58 (1968) 85 pp.
40. Hupp, C. and Palombo, C., "Evaluation of the FHWA Vehicle Classification and Auto Occupancy Sampling Manual." Paper for the Transportation Research Board Annual Meeting, TRB, Washington, D. C. (Jan. 1980).
41. Illuminating Engineering Society of North America, American National Standard Practice for Roadway Lighting. IES, New York, N.Y. (July 1977).
42. Institute of Traffic Engineers, "Goods Transportation in Urban Areas." ITE Informational Report. Washington, D. C. (n.d.).
43. Jeffreys, M. and Norman, M., "On Finding Realistic Turning Flows at Road Junctions." Traffic Engineering and Control (Jan. 1977) pp. 19-21, 25 (Addendum Apr. 1977, p. 207).
44. JHK & Associates, Identification of Procedures Used to Develop Highway Traffic Data, (Technical Memorandum No. 1). Prepared for NCHRP Project 8-26 (Jan. 1982).
45. JHK & Associates, "Interim Materials on Highway Capacity." Transportation Research Circular No. 212, Transp. Research Board (Jan. 1980) 276 pp.
46. JHK & Associates, Refining Traffic Assignments: User's Manual. Prepared for Maryland Dept. of Transp. (1978).
47. JHK & Associates, Traffic Forecast Refinement. Prepared for Washington Council of Govt. and Maryland Dept. of Transp. (Apr. 1978).
48. John Hamburg & Assoc., Inc., "Improved Methods for Vehicle Counting and Determining Vehicle Miles of Travel. Evaluation of the Current State of the Art." NCHRP Project 8-20 (Nov. 1978) 2 vols.
49. Klais, A. E., Simplified Aids for Transportation Analysis, Annotated Bibliography. Wisconsin Dept. of Transp., Madison, Wisc. (Dec. 1975).
50. Klein, R. J., Review of the Baltimore Regional Planning Council Truck Modeling Procedures. Baltimore Region 3-C Process Regional Planning Council, Maryland (Dec. 1980).
51. Kopitzke, K., "Peak Period and Seasonal Adjustments of Traffic for Air Pollution Computations." Transportation Analysis. Minnesota Dept. of Transp. (Dec. 1977).
52. Kugler, B. A., Commins, D. E., and Galloway, W. J., "Highway Noise: A Design for Prediction and Control." NCHRP Report 174 (1976) 194 pp.
53. Kunselman, P. et al., Automobile Exhaust Modal Analysis Model. U. S. Environmental Protection Agency (Jan. 1974).
54. Lefkowitz, B., D'Esopo, D. A. and Korpi, M., Manual for the Gravity Model Computer Programs (Developed for the San Mateo County Traffic Ways Study). Stanford Research Institute, prepared for George S. Nolte Consulting Civil Engineers, Inc., Palo Alto, California (July 1962).
55. Leisch, J. E., "Capacity Analysis Techniques for Design of Signalized Intersections." Public Roads (Aug. 1967; Oct. 1967).
56. Lepore, T. F., An Interdisciplinary Approach to Queue Modeling for Use in Preparing Indirect Source Construction Permit Applications. Connecticut Dept. of Transp. (Feb. 1976).
57. Levenson, M., "Twin City Metropolitan Area Hourly Traffic Volume Study." Transportation Analysis. Minnesota Dept. of Transp., Planning Division (Oct. 1981).
58. Lobb, O., "Summary of Findings: Travel Data." The 1976 Urban and Rural Travel Survey. California Dept. of Transp. (1976).
59. Ludwig, F. et al., User's Manual for the APRAC-2 Emissions and Diffusion Model. Stanford Research Institute, Menlo Park, California, prepared for U. S. Environmental Protection Agency (1977).
60. Maricopa Assn. of Governments, Computer Analysis of West Phoenix Village Core: Documentation for PTI Project (Draft). MAGTPO (Sept. 1980).
61. Maricopa Assn. of Governments, MAGTPO Traffic Projection Procedures and Output (n.d.).
62. Maricopa Assn. of Governments, Peak-Hour Volume Characteristics - 1990 Forecast. Transp. Planning Program (n.d.).
63. Marshment, R., "Turning Movement Estimation Procedure." Middle Rio Grande Council of Governments of New Mexico. Unpublished procedure sent by letter to JHK & Assoc. (Jan. 8, 1982).
64. Mekky, A., "On Estimating Turning Flows at Road Junctions." Traffic Engineering and Control, Vol. 20:10 (Oct. 1979) pp. 486-487.
65. Mellem, N. and Halvorson, J., Study on the Attainment of Carbon Monoxide Standards.

- Minnesota Dept. of Transp. (Aug. 1980).
66. Memmott, J. L. and Buffington, J. L. "Predicting Traffic Volume Growth Rates Resulting From Changes in Highway Capacity and Land Development." Research Report 225-23. Texas Transp. Institute (Jan. 1981) 115 p.
67. Metropolitan Washington Council of Governments (MWCog), "Calibration of a Truck Trip Model for Use in the Transportation Integrated Model System (TRIMS)." Paper. MWCog (Feb. 23, 1978).
68. Metropolitan Washington Council of Governments (MWCog), "TRIMS MODEL (Transportation Integrated Modeling System) - for Subarea and Quick Response Transportation Planning - User's Manual." Technical Report No. 9. MWCog (July 1976).
69. Metropolitan Washington Council of Governments (MWCog), "TRIMZONE (Transportation Integrated Model at Zone - level) - for Highway Network Traffic Assignments." Technical Report No. 13. MWCog (April 1978).
70. Middle Rio Grande Council of Governments, "Arterial Utilization in the Albuquerque Urban Area." Technical Report No. 81 (1981).
71. Minnesota Dept. of Transp., "Methods of Traffic Analysis." System Planning and Analysis Report No. M-137 (n.d.).
72. Neveu, A. J., Quick Procedure to Forecast Rural Traffic. Transp. Statistics and Analysis Section Planning Division, New York State Dept. of Transp. (Oct. 1981).
73. Norman, M., Hoffman, N. and Harding, F., "Non-Iterative Methods for Generating a Realistic Turning Flow Matrix for a Junction." Traffic Engineering and Control (Dec. 1979) pp. 587-589.
74. Norris, G. A. and Nihan, N. L., "Subarea Transportation Planning: A Case Study." Traffic Quarterly, Vol. 33:4 (Oct. 1979).
75. North Central Texas Council of Governments, "Travel Model Development Report - Volume 1." Dallas North Central Subarea Transportation Study (1981).
76. Owen, F., Northtown (T.H. 610) "Windowing" Technique, Transportation Analysis. Minnesota Dept. of Transp. (Oct. 1979).
77. Peduto, F., Cioffi, G. and Albertin, R., Documentation of Selected Programs of the NYSDOT's Simulation System. N. Y. Dept. of Transp. (June 1977).
78. Petersen, W. B., User's Guide for HIWAY-2, A Highway Air Pollution Model. U. S. Environmental Protection Agency (May 1980).
79. Pignataro, L. J. et al., "Traffic Control in Oversaturated Street Networks." NCHRP Report 194 (1978) 152 pp.
80. R. H. Pratt Assoc., Inc., Low Cost Urban Transportation Alternatives: A Study of Ways to Increase the Effectiveness of Existing Transportation Facilities. Prepared for Dept. of Transp., Washington, D. C. (Jan. 1973).
81. Rosas, B. et al., Measuring and Modeling Carbon Monoxide at a High Volume Intersection. Minnesota Dept. of Transp., Federal Highway Admin. (Dec. 1980).
82. Rowan, N. J., Woods, D. L., and Stover, V., Alternatives for Improving Urban Transportation: A Management Overview. U. S. Dept. of Transp., Federal Highway Admin., Washington, D. C. (Oct. 1977).
83. Rudder, F. F., Jr., Lam, D. F. and Chueng, P., User's Manual: FHWA Level 2 Highway Traffic Noise Prediction Model, Stamina 1.0. Science Applications, Inc., prepared for U. S. Dept. of Transp., Washington, D. C. (May 1979).
84. Sanders, D. B. and Reynen, T. A., Characteristics of Urban Transportation Systems - A Handbook for Transportation Planners. Deleuw, Cather & Co., prepared for U. S. Dept. of Transp., Washington, D. C. (May 1974).
85. Shallal, L. and Khan, A. M., "Predicting Peak-Hour Traffic." Traffic Quarterly, Vol. 34:1 (Jan. 1980).
86. Simons, N. et al., Urban Goods Movement Program Design. Battelle, prepared for U. S. Dept. of Transp., Washington, D. C. (June 1972).
87. Skinner, L. E., Comparative Costs of Urban Transportation Systems. U. S. Dept. of Transp., Federal Highway Admin., Washington, D. C. (June 1978).
88. Sosslau, A. B. et al., "Quick-Response Urban Travel Estimation Techniques and Transferable Parameters, User's Guide." NCHRP Report 187 (1978) 229 pp.
89. Sosslau, A. B. et al., "Travel Estimation Procedures for Quick Response to Urban Policy Issues." NCHRP Report 186 (1978) 70 pp.
90. Stanford Research Institute, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements. American Assn. of State Highway and Transportation Officials (1977).
91. Stanford Research Institute, "Procedures for Estimating Highway Users Costs, Air Pollution, and Noise Effects". NCHRP Report 133 (1972) 127 pp.
92. Texas State Dept. of Highways and Public Transp., Traffic Engineering Programs: Passer II-80 (1980).
93. Tittmore, L. H. et al., An Analysis of Urban Travel By Time of Day. Peat, Marwick, Mitchell & Co., prepared for Dept. of Transp., Washington, D. C. (Jan. 1972).
94. U. S. Dept. of Commerce, "Documentation of Nine Methods for Estimating Transit Usage." Modal Split, Vol. 20, App. 48. (Dec. 1966).
95. U. S. Dept. of Commerce, Traffic Assignment Manual. Bureau of Public Roads, Office of Planning (June 1964).
96. U. S. Dept. of Transp., An Introduction To Urban Development Models and Guidelines For Their Use In Urban Transportation Planning. Federal Highway Admin., Washington, D. C. (Oct. 1975).
97. U. S. Dept. of Transp., An Introduction to Urban Travel Demand Forecasting - A Self-Instructional Text, (User-Oriented Materials for UTPS). Federal Highway Admin., Washington, D. C. (1977).
98. U. S. Dept. of Transp., Applications of New Travel Demand Forecasting Techniques to Transportation Planning: A Study of Individual Choice Models. Federal Highway Admin., Washington, D. C. (Mar. 1977).
99. U. S. Dept. of Transp., Calibrating & Testing a GRAVITY MODEL for Any Size Urban Area. Federal Highway Admin., Washington, D. C. (Oct. 1973).
100. U. S. Dept. of Transp., Caline 3 - A Graphical Solution Procedure for Estimating Carbon Monoxide (CO) Concentrates Near Roadways. Federal Highway Admin., Washington, D. C. (Dec. 1980).
101. U. S. Dept. of Transp., Energy Considerations in Transportation Planning. Federal Highway Admin., Washington, D. C. (Mar. 1979).
102. U. S. Dept. of Transp., Energy Requirements for Transportation Systems. Workshop notes, sponsored by Federal Highway Admin., Office of Environmental Policy, Washington, D. C. (June 1980).
103. U. S. Dept. of Transp., Evaluating Urban Transportation System Alternatives. Asst. Secretary for Policy and International Affairs, Office of Transp. Economic Analysis, Washington, D. C. (Nov. 1978).
104. U. S. Dept. of Transp., FHWA Computer Programs for Urban Transportation Planning. Federal Highway Admin., Washington, D. C. (July 1974).
105. U. S. Dept. of Transp., FHWA Traffic Noise Model (Computer Printout). Federal Highway Admin., Washington, D. C. (Nov. 1981).
106. U. S. Dept. of Transp., General Information.

- Federal Highway Admin., Washington, D.C. (Apr. 1977) pp. 289-291.
107. U. S. Dept. of Transp., Urban Transportation Planning. Federal Highway Admin., Washington, D.C. (Mar. 1972) Chap. VII.
  108. U. S. Dept. of Transp., Highway Travel Forecasts: Population, Economics, Fuel, Travel. Federal Highway Admin., Washington, D. C. (Nov. 1974).
  109. U. S. Dept. of Transp., How to Prepare the Transportation Portion of Your State Air Quality Implementation Plan. Federal Highway Admin. with cooperation of U.S. Environmental Protection Agency, Washington, D. C. (Nov. 1978).
  110. U. S. Dept. of Transp., "Interim Project Development Guidelines, 5-4-1." Noise Analysis Considerations - FHWA Standards, (Transmittal No. 17). Development Division, Federal Highway Admin., Washington, D. C. (July 16, 1976).
  111. U. S. Dept. of Transp., PLANPAC/BACKPAC: General Information. Federal Highway Admin., Washington, D. C. (1977).
  112. U. S. Dept. of Transp., Signal Operations Analysis Package (SOAP - Five Volumes). Federal Highway Admin., Washington, D. C. (1979).
  113. U. S. Dept. of Transp., Trip Generation Analysis. Federal Highway Admin., Washington, D. C. (Aug. 1975).
  114. U. S. Dept. of Transp., Urban Origin-Destination Surveys. Federal Highway Admin., Washington, D. C. (1973).
  115. U. S. Dept. of Transp., Urban Transportation Planning System (UTPS), Reference Manual. Federal Highway Admin., Washington, D. C. (Apr. 1977).
  116. U. S. Dept. of Transp., Urban Trip Distribution Friction Factors. Federal Highway Admin., Washington, D. C. (1974).
  117. U. S. Environmental Protection Agency, Carbon Monoxide Hot Spot Guidelines, Vols. I - VI. Office of Air Quality Planning and Standards, Research Triangle Park, N. C. (Aug. 1978).
  118. U. S. Environmental Protection Agency, Guidelines for Air Quality Maintenance Planning and Analysis, Volume 9: Evaluating Indirect Sources. Office of Air and Waste Management, Research Triangle Park, N. C. (Jan. 1975).
  119. Wang, J. J., Route Analysis Fundamentals. Washington Dept. of Highways, (n.d.)
  120. Webster, F. V. et al., "Traffic Signals." Road Research Technical Paper No. 56. Road Research Laboratory, England (1966).
  121. Westinghouse Electric Corp., Westinghouse Street Lighting Engineering Guide, B-5460 (n.d.).
  122. Wisconsin Dept. of Transp., North Fitchburg Transportation Study. Division of Planning, Madison, Wisc. (Dec. 1975).
  123. Wisconsin Dept. of Transp., "Revisions to Chapter 25: Socioeconomic Factors." Facilities Development Manual, (Transmittal No. 45). Division of Transp. Districts, Madison, Wisconsin (Nov. 16, 1981).
  124. Yale Bureau of Highway Traffic, "Comparative Analysis of Traffic Assignment Techniques With Actual Highway Use." NCHRP Report 58, HRB (1968) 85 pp.
  125. Yupo, C., A Review of Operational Urban Transportation Models. Peat, Marwick, Mitchell and Co., prepared for U. S. Dept. of Transp., Washington, D. C. (Apr. 1973).
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